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From the Orthopaedic Department of Tel Hashomer Hospital/Rechovot/Israel
Tel Aviv Med School

THE VASCULAR SUPPLY TO THE EPIPHYSEAL PLATE UNDER NORMAL AND PATHOLOGICAL CONDITIONS

By

E Spira & I Farin

Received 10 I 66

INTRODUCTION

There are four main sources for the bloodsupply to the growing long bones

1 The epiphyseal vessels enter the area through the capsule and the perichondrium and anastomose very freely among themselves

2 The periosteal vessels supply the outer side of the cortex and anastomose with the arterioles of the endosteum

3 The nutrient artery has an ascending and descending branch supplying the metaphyses and the endosteum

4 The metaphyseal vessels enter the bone from the periosteum next to the metaphysis and supply the outer parts of the metaphysis They anastomose with the branches of the nutrient artery (Figure 1)

Purpose of this study

The vascular supply to the epiphyseal plate in particular is the purpose of this paper We felt that our knowledge in this field will contribute to its better understanding

Our studies were performed on rabbits aged 4 weeks (400–500 g weight) with older or younger animals being used when age was the decisive factor

The epiphyseal plate chosen for our study was the distal ulnar epiphysis The changes were recorded both under normal and pathological conditions

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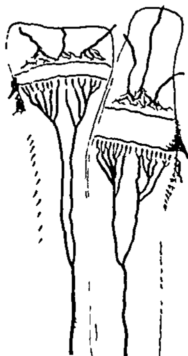


Figure 1. The main sources for the bloodsupply to the epiphyseal plate

I. NORMAL CONDITIONS

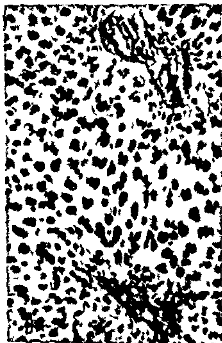
a) *Vascular Channels*

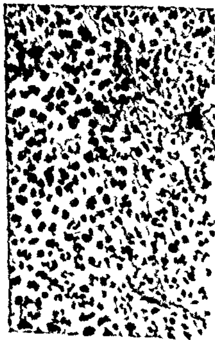
At the age of 4 weeks every microscopic section revealed bloodvessel conducting channels invading the epiphyseal plate from the epiphysis



Figure 2. A Longitudinal section of radial epiphyseal ossification centre of a rabbit (age 14 days) illustrating a cartilage channel leaving the centre in the direction of the metaphysis (× 12)

Figure 2 B C and D Transverse sections through the epiphyseal cartilage of a rabbit (14 days old) Gradual diminution in size of the channel as it reaches the depth of the cartilage plate (× 200)







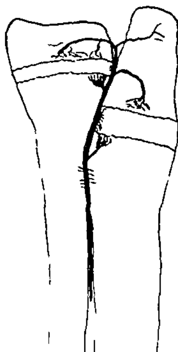


Figure 3 Distribution of interosseous artery with branches to the epi and metaphyseal sides of the epiphyseal plate of radius and ulna

toward the metaphysis These vessels ended in the hypertrophic zone of the plate At the age of 8 weeks the number of these vessels dropped to 27 per cent and at the age of 10 weeks only remnants could be seen

The depth to which these vascular channels invaded the plate diminished too and at 6 weeks they could be seen only in the germinative zone

These vessel conducting channels have a characteristic appearance They are lined with flat cells most probably derived from the perichondrial layers They enter the area of the developing epiphyseal plate

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Figure 4 Disturbance of metaphyseal bloodsupply by a drilled hole of 3 mm size in different relations to the plate 2 days after experiment

A–C Micropaque angiographs (× 10)

A Drilled hole in the middle and near the plate completely disturbing the metaphyseal bloodsupply

B Drilled hole far from the plate with mild disturbance

C Closely drilled hole excentrically placed disturbing 2/3 of the bloodsupply

D Histological section (7 μ × 10) Enlargement of hypertrophic zone in the disturbed area of the metaphysis leaving the other part normal

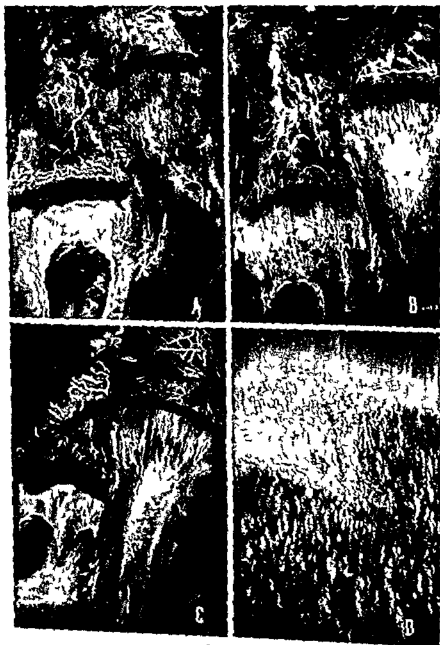


Figure 3

from the epiphysis and the perichondrium The vessels inside the channels appear together in bundles of arterial and venous capillaries These channels themselves lie buried in the growing cartilage masses like in a rising dough Only the collapsed tracts of these channels can be seen in the developed plate (*Spira, Farin & Karplus*) (Figure 2)

b) *Interosseous Artery*

We observed a large vessel a branch of the ulnar artery lying between the distal thirds of the radius and ulna We named it the interosseous artery From this vessel many branches of various sizes enter the metaphysis and the epiphysis of both bones

Their final branching is in the form of the typical umbrella on the epiphyseal side and as the erect loops on the metaphyseal side In very young animals, these branches enter the epiphyseal ossification centre from the epiphyseal side and continue into the epiphyseal plate

The participation of this vessel in the bloodsupply to the epiphyseal plate is varying Our experiments have shown however that the metaphyseal branches may supply a third of the plate On the epiphyseal side the supply is less well defined because of the rich anastomoses in this area But here too this vessel contributes considerably to the normal vascular supply (Figure 3)

II PATHOLOGICAL CONDITIONS

a) *Disturbance of the Metaphyseal Bloodsupply*

1) *Drilling* A hole was drilled with a 3 mm dental drill into the metaphysis (54 rabbits)

Depending on the location different extents of disturbances in the enchondral ossification were observed The disturbance on this side was complete only when the *drillhole was near the plate* The hypertrophic zone was enlarged on this site while the rest of the plate grew in the normal way In every experiment a complete restoration of the *normal enchondral ossification was established after 7 days* (Figure 4)

2) *Osteotomy* An osteotomy through the metaphyseal area was done 3–4 mm proximal to the plate (70 rabbits)

The immediate effect was a haemorrhage between the fragments As a consequence of this the enchondral ossification was interrupted and the hypertrophic zone was enlarged (Figure 5) If contact between the fragments was close the enchondral ossification started again after 4





Figure 5 Disturbance of metaphyseal bloodsupply by osteotomy 24 hours after experiment A Micropaque angiograph (× 10) No filling of bloodvessels in ulnar half of metaphysis B Longitudinal histological section (7 μ × 12) Haemorrhage and engorgement distally from the lesion Enlargement of hypertrophic zone in the same area



A Micropaque angiograph (× 10) line of osteotomy on the ulnar half of bone area filled with contrast material Distally—fine new vessels reaching nearly to the normal height From the epiphyseal side opposite the lesion epiphyseal vessels intrude the epiphyseal plate

B Histological section of the same area (7 µ × 12) Remnants of line of osteotomy Progress of enchondral ossification with new trabeculae leaving an area of enlarged hypertrophic zone where revascularisation is still disturbed

Figure 6 Disturbance of metaphyseal bloodsupply by osteotomy 4 days after experiment



Figure 7 Histological detail of the revascularised area (7 d × 200) of Fig 6 Direct vascular invasion of vessels into the hypertrophic zone and formation of sinuses with contrast material

days After 7 days the previous line of interruption can be recognized by the thinner bone trabeculae beyond it marking the formation of new spongy bone (Figure 6)

If the clot between the fragments was large the enchondral ossification was considerably delayed even for a few days The masses of hypertrophic cells were invaded from the sides by metaphyseal vessels leaving behind them remnants of hypertrophic cells Where the revascularisation was delayed for more than 4-5 days vessels from the epiphyseal side were observed invading the epiphyseal plate

The metaphyseal vascularisation was observed as a direct invasion of vessels into the hypertrophic zone or the formation of sinuses from which vessels developed (Figure 7) In areas where revascularisation of the enchondral ossification was somewhat impaired a fibrosis of the



Figure 8 Traumatic epiphysiolysis with displacement Longitudinal histological sections A 5 days after experiment (7 µ × 12) vessel conducting channel protrudes through the epiphyseal plate B Detail of the previous section (× 80) contrast material in the arterial capillaries flat cells lining the channel walls





Figure 9 Traumatic epiphysiolysis with displacement A 7 days after experiment (7 μ × 40) Two vessel conducting channels invading the enlarged hypertrophic zone and starting enchondral ossification B 10 days after experiment (7 μ × 1[illegible]) Restitution of the normal size of the epiphyseal plate The channels have retreated and remnants are still visible in the epiphyseal plate



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Figure 10 Disturbance of the epiphyseal bloodsupply by osteotomy near to the plate (× 1?) A big clot fills the gap of the site of the osteotomy injuring the germinative zone of the plate in the centre

c) *Disturbances of the Epiphyseal and Metaphyseal Blood Supply*

This disturbance was performed by means of a double rotating dental saw performing the two osteotomies in one stage on either side of the plate

1) Both osteotomies were placed at a distance of 3-4 mm from the plate (30 rabbits)

If the contact between the fragments was close revascularisation occurred rapidly like in the separate previous experiments At the latest after 14 days the structure and growth of the plate were restored

2) The osteotomies were placed very close to the plate (30 rabbits)

Due to the technical difficulties the cuts were sometimes nearer to the metaphyseal or epiphyseal side of the plate

Again the events of the separate injuries of the sides of the plate were repeated Only if a great haematoma hampered the revascularisation from the metaphyseal side epiphyseal vessels entered the area of the epiphyseal plate (Figure 11 a) If the epiphyseal bloodsupply is disturbed metaphyseal vessels extend towards the epiphyseal side of

bone marrow together with an unusual early bone maturation were observed.

No definite disturbance was observed in this series.

3) *Traumatic Epiphysiolysis.* A traumatic epiphysiolysis with dislocation to 90° of the distal fragment was performed (100 rabbits). No reposition was attempted.

A large haematoma was separating the fragments. Enchondral ossification was disturbed and the hypertrophic zone enlarged. After 5 days, vessel conducting channels appeared from the epiphyseal side of the plate and protruded deeply into the epiphyseal plate. They can be observed to reach into the metaphyseal area, starting there by enchondral ossification. These channels have the same appearance as described before (Figure 8) (*Spira, Farin & Karplus*). After 7 days, multiple epiphyseal vascular channels are entering the epiphyseal plate in several places. The vessels invade the enlarged hypertrophic zone (Figure 9a). After 10 days from the beginning of the experiment, the enchondral ossification, caused partly by the epiphyseal vessels, was restored to normal conditions. At the same time, the vessel conducting channels retreated into the germinative zone and the channels collapsed again (Figure 9b).

In 4 experiments, this regeneration did not occur. Instead, the channel conducting vessels enlarged their invasion of the metaphyseal area and finally a fibrous or bony gap divided the epiphyseal plate into separate parts.

b) *Disturbance of the Epiphyseal Bloodsupply*

1) An osteotomy was performed at a distance of 8–10 mm from the plate (25 rabbits).

No impairment of circulation to the epiphyseal plate could be observed.

2) An osteotomy was performed very near to the plate (25 rabbits).

When the osteotomy did not directly injure the bony plate or the germinative zone, no injury to the plate occurred, due to the enormous vascular branching and anastomosing in the area. But if the injury to the plate was direct, this area lost its staining and the adjacent columns did not form. The development of the plate in this area was definitely disturbed. But no consequences toward the further development of the plate could be observed (Figure 10).



Figure 10. Disturbance of the epiphyseal bloodsupply by osteotomy near to the plate (7 d × 17). A big clot fills the gap of the site of the osteotomy injuring the germinative zone of the plate in the centre

c) *Disturbances of the Epiphyseal and Metaphyseal Blood Supply*

This disturbance was performed by means of a double *rotating dental* saw performing the two osteotomies in one stage on either side of the plate.

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Figure 11 Disturbance of epiphyseal and metaphyseal bloodsupply near the epiphyseal plate Micropaque angiographs (1 0 μ × 10) 7 days after experiment
A Metaphyseal bloodsupply hampered by the haematoma epiphyseal vessels enter the area of the epiphyseal plate
B Epiphyseal bloodsupply hampered by the osteotomy metaphyseal vessels extend towards the epiphseal plate The metaphyseal blood supply itself is delayed on the ulnar third of the metaphysis

the plate (Figure 11 b) In spite of the severe injury however the function of the plate was restored after a month In severe injuries a similar observation like in traumatic epiphysiolysis was recorded causing fibrous or bony bridges in the epiphyseal plate (Figure 12)

3) Similar observations were made on autotransplantations of the plate (30 rabbits)

d) *Identity of the Epiphyseal and Metaphyseal Vessels*

In the series of autotransplantations two plates with adjacent bone were accidentally turned round 180 to their axis This offered a chance

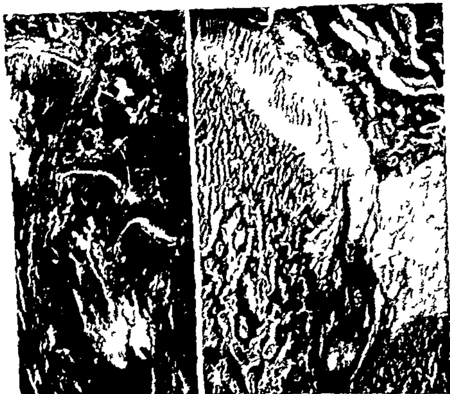


Figure 12 Disturbance of epiphyseal and metaphyseal bloodsupply near the epiphyseal plate 30 days after experiment

A A fibrous bridge divides the two halves of the epiphyseal plate delaying the ulnar half

B Histological section (? × 40) from A showing the fibrous bridge

to study the bloodsupply under these conditions In both instances the vessels preserved their original form as "loops" and "umbrellas" In both cases the contact between the fragments was very close and therefore revascularisation occurred very quickly (Figure 13)

c) Disturbance of the Nutrient Artery

Resection of part of the diaphysis of the ulna showed enlargement of the hypertrophic zone in the ulna due to a disturbance of the metaphyseal bloodsupply To our surprise this enlargement did not occur in the distal ulnar epiphysis only but also in the epiphyseal plate of the radius (Figure 14)

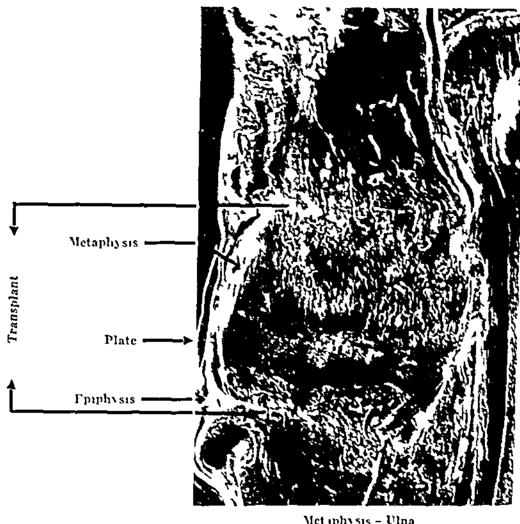


Figure 13. Epiphyseal plate with adjacent bone turned round 180° to its axis (7 days after experiment). Preservation of the characteristic original form of "loops" on the metaphyseal side and of "umbrellas" on the epiphyseal side is shown.

This was a chance observation in 16 experiments while studying bone formation after resection of the diaphysis.

DISCUSSION

This study on the bloodsupply to the epiphyseal plate has produced some interesting observations.

The existence of vascular channels in the epiphyseal plate were observed already by *Langer* (1876). A similar observation was re-





Figure 14 Disturbance of the nutrient artery in the diaphysis of the ulna caused enlargement of the hypertrophic zone of the distal plate in the ulna and the radius

A Total view

B Distal ulnar and radial epiphyses

ported by *Budder* (1906) He described connections with diaphyseal vessels In this opinion these vessels play a significant part in the nutrition of the cartilage and in the ossification *of the epiphysis* *Tilling* (1958) surveyed the literature and described vascular channels perforating the epiphyseal plate in calves of 2 weeks of age He made similar observations on the human foetus in the upper tibia and lower *femur* epiphysis In his observations on calves and cows he saw vessels anastomosing with metaphyseal vessels after perforating the *epiphy*seal plate from the epiphysis He considers three sources for the metaphyseal vessel 1 the nutrient 2 the metaphyseal vessels joining the *nutrient* and 3 the epiphyseal vessels which reach the area from the epiphysis through the epiphyseal plate

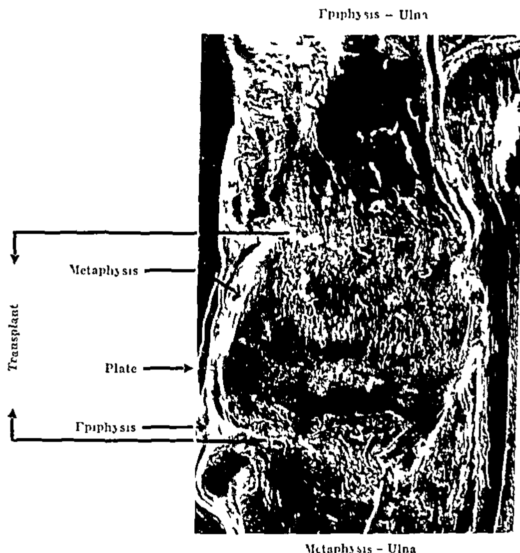


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Besides these observations most of the students of this problem deny the existence of such vascular channels in the epiphyseal plate. The plate is *considered a barrier for vascular connections between the epi-* and metaphysis. Only in the perichondrium are vessels which pass longitudinally to the metaphysis from the epiphysis and supply both superficial areas of the bone (*De Marneffe, Harris* and Co-workers, *Trueta* a. o.)

In previous studies on growing rabbits (*Spira, Farin, Karplus*) we could demonstrate vascular channels containing arterioles and venules in all histological sections till the age of 4 weeks. Thereafter the vessels gradually decreased in number and in depth of penetration *until* at the age of *10* weeks no channels were seen in the plate, only the tracts of the collapsed channels remaining. Under pathological conditions however when the metaphyseal bloodsupply is severely disturbed for a few days, these vascular channels do reappear. These channels are lined with flat cells and again contain arterioles and venules like under normal developing conditions.

But this time the channels penetrate the epiphyseal plate to its full depth even reaching the metaphysis. We observed them functioning in the metaphysis like metaphyseal vessels starting enchondral ossification *in* areas where *gross enlargement of the hypertrophic zone had* occurred. This means that these epiphyseal vessels undertake functions which have been considered the main task of metaphyseal vessels. These vascular channels can however disappear again and collapse again to tracts if the revascularisation of the plate has started again from the metaphyseal side. But they can expand to fibrous and bony bridges dividing the plate into different parts if the metaphyseal blood supply has been severely interrupted. This of course means the complete disorganisation of the epiphyseal plate. Similar observa*tions* were also *made under other experimental conditions* (*Troupp, Brashear*)

The question remains whether these vascular channels are the old collapsed channels or new ones. *Harris* a. o. (1965) maintain that these vascular channels lie in the cartilage anlage of the epiphyseal bone plate. But after the bone plate of the epiphysis has *formed in mature* animals these vessels lie in bony channels so that only the vascular tufts are in contact with the cartilage cells. Our observations were made on animals 6 weeks of age at a time at which under normal conditions such channels can be seen only in a small number in the germinative zone. This means that this mechanism of penetration of

vascular channels exists only in growing animals and not in mature ones This question will be studied separately The fact does exist however that the epiphyseal vessels protrude into the area of the epiphyseal plate they may even invade the metaphysis They are capable of recollapse when the revascularisation has started and they can also develop into bony bridges

We have not observed a similar behaviour on the side of the metaphyseal vessels if a vascular impairment exists on the epiphyseal side of the plate We saw metaphyseal vessels invading the area of the plate in some doublesided interruptions of the bloodsupply They never reached the area of the germinative zone This difference in behaviour could be explained by the difference of the anatomical character of both vessel groups While the epiphyseal vessels anastomose very richly amongst themselves even in the area of the endbranches in the umbrella the metaphyseal loops are arranged more in segmental form supplying their specific area only

The vessels on both sides of the plate do preserve their anatomical characteristics even if they are turned round 180 provided that the contact between the fragments is very close and revascularisation of the area takes place very quickly Additional studies have to show the further behaviour of these vessels

According to *Trueta* and co workers the epiphyseal vessels function as vascular supply to the germinative zone of the plate while the metaphyseal vessels function as enchondral ossification In our observations on growing animals these epiphyseal vessels function for the supply of the growing cartilage anlage of the plate and only after the epiphyseal plate is fully developed they function in the known form Under pathological conditions these vascular channels of the epiphysis are capable of substituting for the metaphyseal vessels in their function The interosseal artery described by us as a vessel supplying both the metaphyseal and the epiphyseal side of both bones in the rabbit is also an example that the function of both vascular supplies are not purely specific to one side of the plate At present we have no evidence for a mechanism functioning in this area and permitting interchange of functions between both vascular supplies But such a mechanism seems very probable

We observed neural influence on the growth of the epiphyseal plate when diaphyseal bone was resected One could expect that the epiphyseal plate of the same bone would react as was observed by *Heikel* & *Troupp* but that the epiphyseal plate of the neighbouring bone also

reacts by reflex was so far unknown and has to be studied in further detail

It appears from our study that every experimental disturbance of the blood supply to the epiphyseal plate in the growing animal can be overcome *if the contact between the fragments is close and the clot* formation is kept to a minimum Only direct disturbance of the germinative zone causes a localised distraction of the normal plate formation This observation is of especial interest for experimental transplantations which are to our knowledge completely dependent on quick revascularisation This observation has been made repeatedly by *Haas, Brashear, Harris, Ring* a o

SUMMARY

The vascular supply to the distal epiphyseal plate of the ulna in rabbits was studied under normal and experimental conditions

The existence and behaviour of blood vessel conducting channels crossing the epiphyseal plate from the epiphyseal to the metaphyseal side were described under different conditions There is no similar behaviour of the vessels on the metaphyseal side of the plate The difference in behaviour seems to lie in the anatomical character of the vessels

The vessels on both sides of the plate preserved their characteristics even if the plate was turned round 180

Under pathological conditions the epiphyseal vessels can substitute the function of the metaphyseal vessels

A vessel supplying both sides of the plate of both forearmbones is described

Every experimental disturbance of the blood supply to the epiphyseal plate in the growing animal can be overcome under certain conditions

RESUME

La vascularisation de la plaque epiphysaire distale de l articulation du coude chez les lapins a ete etudiee dans des conditions normales et expérimentales

La présence et le comportement des canaux conducteurs du vaisseau sanguin traversant la plaque epiphysaire du cote de l epiphyse au coté de la metaphyse sont decrits en partant de *conditions variees* Il n y a pas de comportement similaire des vaisseaux du cote metaphy

saire de la plaque La difference de comportement semble etre liée au caractère anatomique des vaisseaux

Les vaisseaux des deux cotes de la plaque conservent leurs caractéristiques meme si la plaque est retournee 180°

Dans des conditions pathologiques les vaisseaux épiphysaires peuvent se substituer dans leur fonction aux vaisseaux metaphysaires

Il est donné une description d un vaisseau approvisionnant les deux cotés de la plaque des deux os de l avant bras

Toute perturbation experimentale de l apport sanguin a la plaque epiphysaire chez l animal en croissance peut etre redressee dans certaines conditions

ZUSAMMENFASSUNG

Die Gefassversorgung der distalen Epiphysenplatte der Ulna von Kaninchen wurde unter normalen und experimentellen Bedingungen studiert

Das Vorhandensein und das Verhalten von Blutgefässen welche in Kanalen die Epiphysenplatte in Richtung der Metaphyse kreuzen wurden unter verschiedenen Bedingungen beschrieben Ein ähnliches Verhalten der Gefasse an der Metaphysenseite der Platte besteht nicht Die Verschiedenheit des Verhaltens scheint im anatomischen Charakter der Gefasse zu liegen

Die Gefasse zu beiden Seiten der Platte bewahrten ihre charakteristischen Eigenschaften selbst wenn die Platte um 180 gedreht *wurde*

Unter pathologischen Verhaltnissen konnen die Gefasse der Epiphyse die Funktion der Metaphysengefasse ubernehmen

Ein Gefass das beide Seiten der Epiphysenplatte beider Unterarmknochen versorgt wird beschrieben

Jede experimentelle Storung der Blutversorgung der *Epiphysen*platte des wachsenden Tieres kann unter gewissen Bedingungen uberwunden werden

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reacts by reflex was so far unknown, and has to be studied in further detail

It appears from our study that every experimental disturbance of the blood supply to the epiphyseal plate in the growing animal can be overcome if the contact between the fragments is close and the clot formation is kept to a minimum Only direct disturbance of the germinative zone causes a localised distraction of the normal plate formation This observation is of especial interest for experimental transplantations which are to our knowledge completely dependent on quick revascularisation This observation has been made repeatedly by *Haas, Brashear, Harris, Ring* a o

SUMMARY

The vascular supply to the distal epiphyseal plate of the ulna in rabbits was studied under normal and experimental conditions

The existence and behaviour of blood vessel conducting channels crossing the epiphyseal plate from the epiphyseal to the metaphyseal side were described under different conditions There is no similar behaviour of the vessels on the metaphyseal side of the plate The difference in behaviour seems to lie in the anatomical character of the vessels

The vessels on both sides of the plate preserved their characteristics even if the plate was turned round 180°

Under pathological conditions the epiphyseal vessels can substitute the function of the metaphyseal vessels

A vessel, supplying both sides of the plate of both forearmbones is described

Every experimental disturbance of the blood supply to the epiphyseal plate in the growing *animal can be overcome under certain conditions*

RESUME

La vascularisation de la plaque épiphysaire distale de l'articulation du coude chez les lapins a été étudiée dans des conditions normales et expérimentales

La présence et le comportement des canaux conducteurs du vaisseau sanguin traversant la plaque épiphysaire du coté de l'épiphyse au coté de la métaphyse sont décrits en partant de conditions variées Il n'y a pas de comportement similaire des vaisseaux du coté métaphy-

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EFFECT OF HYPERBARIC OXYGENATION ON LONGITUDINAL GROWTH OF BONES

By

BJORN MAURITZ PERSSON

Received 24 VIII 66

The increased rate of growth in length of bones after fractures and osteomyelitis in children gave rise to a surge of interest in the induction of such growth stimulation in experimental animals in the middle of the 19th century (*Stanley* 1849 *Ollier* 1867 *von Langenbeck* 1869) As early as 1869 *von Langenbeck* implanted ivory plugs in the medullary cavity of the femur and the tibia of a young dog for growth stimulation after 11 weeks the leg was 10 mm longer than the contralateral one In his classical monograph on bone regeneration *Ollier* in 1867 reported that removal of the periosteum of the tibia of rabbits resulted in a relative increase of the growth in length of the bone by 2 5 mm within 3 months He also reported a less regular effect of the implantation of nails in long bones and of the division of nerves in rabbits and dogs Vasomotor paralysis with increased flow was considered as a possible cause of the stimulation of the length growth in these experiments In 1856 *Broca* described a case with an arteriovenous aneurysm of a lower limb which was 3 cm longer than the contralateral leg *Krause* (1861) published a similar case with an arteriovenous aneurysm of the one forearm which was 4 cm longer than the other

On the basis of the above observations it could be assumed that epiphyseal hyperaemia was a common growth stimulant and in 1887 *Helferich* reported the use of induced venous stasis as a clinical therapy in a boy and in a girl with leg length disparity the difference was said to be reduced by 1 , 2 cm by prolonged stasis of the shorter limb

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0.8–9.6 cm longer than the contralateral one while no such difference could be found in any of 25 patients with chronic lymphoedema elephantiasis. The difference was so regular that he thought that it might be used in the distinction between the two diseases. In other words growth in length was promoted by the congestion of the blood but not by the lymph stasis.

Brodin (1955) found the increased growth of the rabbit tibia after periosteal loosening to be associated with an increase in the *blood supply* as judged by photometric determination of the fluorescence of the bone after injection of sodium oxypyrene-sulphonate. Using i.v. P^{32} injection *Watanabe* (1962) reported increased blood supply to the epiphysis after medullary curettage as measured by the radioactivity of bone ash from standardized pieces of the tibia. This increase was proportional to the increase in growth recorded. It was not determined whether these observations depended on tissue affinities altered by the trauma or on change in the arterial blood flow or the blood volume content only.

Summing up there is thus ample evidence that hyperaemia is a cause of accelerated longitudinal growth of bones. This gives rise to the question whether there is an *increased arterial flow* in the affected region as indicated by the experiments of *Trueta* or a mere passive *venous congestion* as suggested by *Hutchinson & Burdeaux*. One main difference between the two theories is the amount of oxygen offered to the growth plate and, in other words, is the growth accelerated by an increased oxygen supply *per se* to the extent that it follows the increased oxygen content of the arterial blood during hyperbaric oxygen breathing. A search of the literature failed to reveal any reports on this problem. It was therefore considered legitimate to study the effect of hyperbaric oxygenation on the rate of bone growth and the preliminary results are presented below.

MATERIAL AND METHODS

The *material* consisted of 64 white rabbits of the same breed. The animals were 5–7 weeks old, they weighed 600–1800 g and represented 12 litters. Pure oxygen at 2 atm absolute pressure was given to 20 rabbits, air at 2 atm abs. to 18 litter mates, pure oxygen at 1 atm abs. to 6 rabbits and air at 1 atm abs. to 12 rabbits. The animals were weighed at the beginning and the end of the experiments. Eight animals (4 that received pure oxygen and 4 that received air) were excluded because of loss of body weight.

The equipment for *oxygenation* by pure oxygen breathing consisted of 2 glass hutches in a pressure chamber, pure oxygen and air in standard cylinders (200 kp)

In more recent years stimulation of epiphyseal growth in length has received extensive attention. Thus *Pearse & Morton* (1930) confirmed the stimulating effect of *venous stasis* on the healing of fractures in dogs and *Hutchinson & Burdeaux* on the growth in length (1954). Artificial *arteriovenous fistulae* have also been found to increase the rate of growth in the length of bones in the dog (*Janes & Musgrove* 1950 and *Keel & Kelly* 1964). *Hiertonn* (1961) and others have reported important growth stimulation after femoral arteriovenous shunting in children. *Intraosseous foreign bodies* e.g. solutions, metals, textiles, skin, ivory and bacteria have been used with varying success (*Wu & Miltner* 1930, *Kishikawa* 1936, *Chapchal & Zeldenrust* 1948, *Wilson* 1951, *Pease* 1952, *Herndon & Spencer* 1953, *Trueta* 1953, *Wilson & Percy* 1956, *Elo* 1960). *Medullary curettage* by *Ferguson* (1930) and *Hansson & Wiberg* (1963), *medullary plugging* by *Trueta* (1953) have been tried but with only fair success (*Carpenter, Dalton* 1956, *Jansen* 1957, *Stahl* 1957). The effect of *division of nerves* and nerve roots has been reviewed and studied by *Troupp* (1961) and *Ring* (1961). *Buchtala* (1948) found *ultrasound* treatment of the epiphysis to produce some acceleration of growth in length, an effect which could not be confirmed by *DeForest et al.* (1953) or by *Vaughan & Bender* (1959). The effect of *roentgen irradiation* has been studied by *Baunach* (1935), *Reidy et al.* (1947) and *Barnhard* (1963), who found small doses to have no clear effect and large doses to retard growth of the epiphysis in birds and dogs. *Short wave diathermy* stimulates bone growth in rats according to *Doyle & Smart* (1963) but not in dogs (*Granberry & Janes* 1963). *Electric stimulation* has been found to have no effect (*Granberry & Janes* 1963) or an irregular and varying effect (*Richards & Stofer* 1959 and *Haas* 1963). *Local heating* has given no stimulation (*Ring & Lee* 1958). The influence of *fractures* on bone growth in children has recently been reviewed by *Guldhammer* (1963) — on the leg, and *Emneus & Hedström*—on the arm (1964).

Though it may be regarded as established that growth in length of a bone is often accelerated by osteomyelites, fractures, foreign bodies, arteriovenous fistulae and venous stasis, no unequivocal evidence has been produced in support of the assumption of *Hutchinson & Burdeaux* (1954) that such acceleration is due to venous stasis hyperaemia as a primary or secondary effect in all cases cited. In this connection it may be convenient to mention an interesting observation by *Servelle* (1948). He reported venographically verified unilateral congenital venous abnormalities of the leg in 14 human beings, whose affected leg was

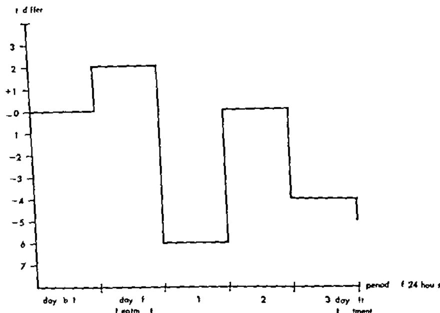


Figure 2 Percent difference of epiphyseal growth distance in p riods of 24 hours betw en oxyg n and air tr ated rabb ts u th one single day of treatment for 2 + 9 + 9 h urs at 9 atm abs of pure oxygen compared to pure a r breathing

ultraviolet l ght microsc pe with a dark field condenser The distance between con secutive bands f OTC is a measure of the growth per 24 hours (Figure 1) Each animal received 4 to 6 injections which thus allowe l measurement of growth during three to f ve 24 hour periods The first interval was used as a normal value the e ond as the day of treatment an l the subsequent days for studying the continued effect on growth The anim ls were tre ted in the pressure chamber between the sec nd and the third injections the third injection being given within one hour of the end of the last period of oxygenation so that the growth rate luring oxygenation fell on one si le and the grow th rate after withdrawal of oxygenation on the other side of the third injection line The proximal part of the left tibia was used for the m cr copical sections The ral l its were killed l v intraperitoneal injection of Evipan® about 1 hour after administration of the last dose of OTC The proximal til ia v as exci e l and fixed in pure ethanol for 1 3 days Slices 60–120 μ in thickness were cut w th a raz r l lade place l parallel to the metaphyseal trabeculae as judged in ne sag ttal an l one fr ntal cut urface Still acc rding to *Hansson* the slices were then treated in xylol for 5–10 minutes and mounted in DePeX on glass slides M cro cop c measurements of the l ne intervals were made with a standardized me uring ocular The mean of 5–10 slices measured was used

Te t st the relial ility of the meth d in the hands of the writer 15 animals were given 4 injection each an l the growth was measured on the 3 consecutive periods of 12 hours use l For comparison l oth proximal tibiae were excised treated and

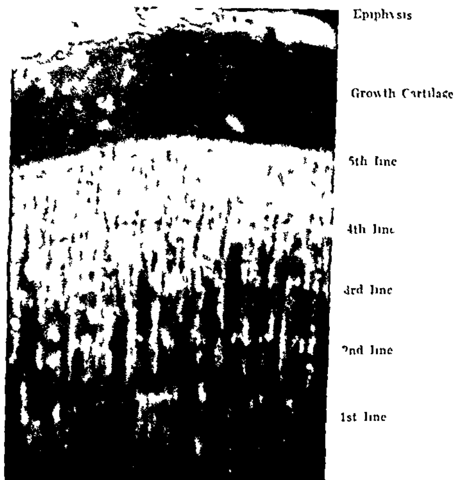
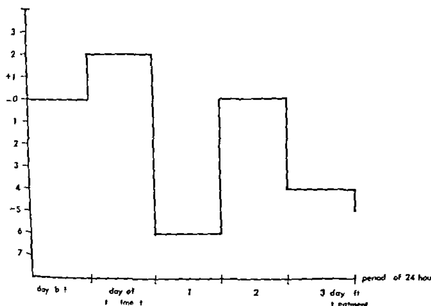


Figure 1 Oxytetracycline fluorescence lines on the metaphyseal side of the proximal epiphyseal growth cartilage of the tibia of rabbits Interval between the lines 24 hours distance about 300 microns

and flowmeters to check the flow through the hutches Pure air or oxygen was conducted through the hutches in the pressure chamber at the rate of 800 litres/hr/kg bodyweight to prevent accumulation of carbon dioxide Two to four animals were placed in each hutch Litter mates were placed in the 2 hutches and treated simultaneously As in clinical practice the animals were treated with oxygen for three 2 hour periods on a single day with an interval of 1 2 hours between consecutive periods of treatment During these intervals the rabbits were resting together outside the hutches Before and after the day of treatment the animals were kept in the same cage as the mother The animals were fed on rabbit pellets and carrots which were given at the same hours every day

Growth was measured by the oxytetracycline (OTC) labelling method described by *Hansson* 1964 The OTC was injected intravenously in a dose of *1 mg/kg bodyweight* each 24 hours Incorporation of the OTC in the zone of calcification on the metaphyseal side of the growth cartilage produces distinct bands of fluorescence in an



F gure I ercent difference of epiphyseal growth distance in periods of 24 hours b tween oxyg n and air treat d rabbits with one single day of treatm nt for 2 + 2 + 2 hours at 2 atm abs of pure oxygen compa ed to pure air breathing

ultraviolet light microscope with a dark field condenser The distan e between con secutive bands of OTC is a measure of the growth per 24 hours (Figure 1) Each animal received 4 to 6 injections which thus all wed measurement of growth during th ee to fi e 24 hour periods The first interval was used as a normal value the e nd as the day of treatment and the subsequent days for studying the continued effect on growth The animals were treated in the pre sure chamber between the econd and the third injections the third injection being given within one hour of the end of the last period of oxygenation so that the growth rate during oxygenation fell n one side and the growth rate after withdrawal of oxygenation on the other ide of the third inject on line The proximal part of the left tibia wa used for the m croscopical sections The rabbits were killed by intraperitoneal injection of F ijan about 1 hour after adm nistration of the la t d se of OTC The proximal tibia was excised and fixed in pure ethanol for 1 3 days Slices 60–1 0 μ in thickness were cut with a razor blade placed parallel t the metaphyseal trabeculae as judged m ne sagittal an l ne frontal cut urface Still ac rding to *Hansson* the slices were then treated in xylol f r 5–10 minutes and mounted in DePeX on glass slides M cr scopic measurements of the line intervals were made with a standardized m asu ing o ular The mean of 5–10 slices measured was used

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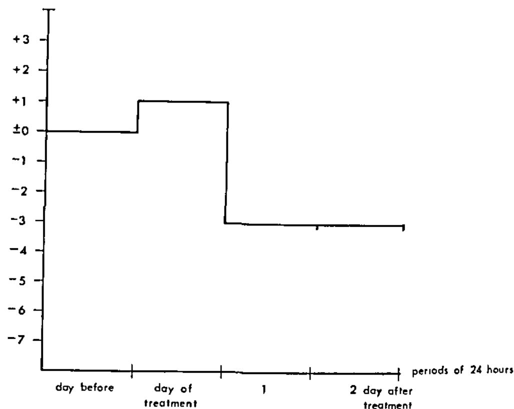


Figure 3 Percent difference of epiphyseal growth distances in periods of 24 hours between oxygen and air treated rabbits with one single day of treatment for 2 + 2 + 2 hours at 1 atm abs of pure oxygen compared to pure air breathing

measured in the way described The differences between the right and left sides of the 45 observations were added and compared with the mean of each interval and thereby gave the mean error of the method which was found to be 9 microns or 3 7 per cent including possible differences between the sides error of obliqueness of the plane of sections relative to the plane of the trabeculae mounting angulation reading error and calculation

RESULTS

The results are summarized in Figures 2 and 3 which give the mean growth ratios on the control day the day of treatment and the subsequent days of observation In each of the 4 groups the mean growth noted was divided by the mean of the first day (before treatment normal value) which was said to represent 100 units The values thus obtained for growth in the oxygen group were divided by the corresponding figures recorded in the corresponding air group In this way factors other than oxygen were excluded i e temperature

humidity, pressure and other possible stressing factors as far as they were the same in the group treated with oxygen and in the one treated with air.

Figure 2 gives the results obtained with oxygen breathing at 2 atm. abs. Figure 3 for oxygen at 1 atm. abs. No experiments were made at 3 atm. abs. because of the risk of toxic effects of the oxygen. The lungs of the animals were regularly examined post mortem. The findings indicated a slight stimulation (about 2 per cent) during oxygen breathing followed by a pronounced depression of growth rate (about 7 per cent) the day after exposure (see Figures 2 and 3). Statistical significance was found only for the depression of growth just mentioned. The material was not large enough to allow final conclusions but continued studies since performed lend support to all the tendencies observed in the present series.

DISCUSSION

The 2 per cent increase of the rate of growth in length of the rabbit tibia during pure oxygen breathing for 2 + 2 + 2 hours in a single 24 hour period implies that the increase in rate of growth during the actual 6 hours of treatment exceeded 2 per cent, assuming that growth proceeded at a normal rate during the intervals between the consecutive exposures. But judging from the deceleration of growth on the day after treatment, the rate of growth between and after the 3 exposures to oxygen might have been suppressed and thereby masked part of an increase in growth during the actual treatment. This possibility is being checked in investigations now in progress.

The inhalation of oxygen at an increased partial pressure suppresses the circulation in the limbs as measured by venous occlusion plethysmography and by Xenon clearance (*Bird & Telfer* 1965). At 2 atm. abs. of pure oxygen the reduction was about 28 per cent. If these figures hold for the rabbit and for the exposure periods used in the present investigation as well as for the blood flow in the epiphyseal bone per se, it would decrease the supply of blood-borne growth substances including oxygen. According to Handbook of Respiration (*Dittmer & Grebe* 1958) the oxygen capacity of 100 ml of blood is 20 ml during air brathing at 1 atm. abs. and this figure is raised to 20.9 ml of haemoglobin-bound oxygen plus another 4.3 ml in physical solution during oxygen breathing at 2 atm. abs. This means that a rise in inspired partial pressure of oxygen from about 150 mm Hg to about 1500 mm Hg increases the oxy-

gen capacity from 20 to 25.2 ml/100 ml of blood, an increase of about 25 per cent. The vasoconstriction in question would tend to reduce the attempted tissue hyperoxygenation as well as the supply of other bloodborne growth factors. Another point of interest is the possible retention of carbon dioxide caused by the reduced transport capacity of the haemoglobin when blocked by the hyperoxygenation. The maturation time for the cells of the growth plate has been determined to be 2–4 days from the zone of proliferation to the zone of calcification (*Messier & Leblond* 1960) and this causes difficulties in the interpretation of the diphasic stimulation and retardation recorded. The stimulation during the day of treatment was achieved without any venous stasis but may be with a local carbon dioxide accumulation. It was probably achieved without any increase in local blood flow but with a rise in arterial oxygen pressure. These problems will receive further attention.

Apart from the information that may be obtained on the physiological role played by oxygen in bone growth it may be of interest for a future development of therapeutic hyperbaric oxygenation in orthopaedics to know the effect of oxygen treatment in the longitudinal growth. Because of its quantitative measurability it forms another parameter of the biological effects of hyperbaric oxygenation.

SUMMARY

From clinical experience and experimental work on longitudinal growth of bones it is known that the growth rate can be accelerated locally by certain inflammatory conditions as well as by venous stasis and arteriovenous shunts. In an attempt to investigate whether this stimulation is caused by *arterial hyperaemia* or by passive *venous stasis* young rabbits were exposed to *pure oxygen breathing* at one and two atm. abs. pressure for 2 + 2 + 2 hours on one single day and the growth rate of the proximal tibial growth plate was studied by oxytetracycline labelling according to *Hansson*. The subsequent daily growth was compared with that in *litter mates* exposed to air at the same pressures for the same periods. Oxygen breathing seemed to accelerate growth by 2 per cent during the day of treatment followed by a deceleration of 7 per cent the day after treatment. The results are discussed, mechanisms involved are evaluated and the continued work is outlined.

RESUME

L'expérience clinique et les travaux d'expérimentation ont montre que dans la croissance longitudinale des os le taux de croissance peut etre accéléré localement par certaines conditions inflammatoires ainsi que par une stase veineuse ou des derivations arterio veineuses Dans le but de rechercher si cette stimulation est causee par *hyperemie arterielle* ou par *stase veineuse* passive de jeunes lapins ont ete exposes a aspirer de l'oxygene pur a une pression d'une ou 2 atm abs pendant 2 + 2 + 2 heures dans le meme jour Le taux de la croissance de la plaque de croissance tibiale proximale a ete etudie par la methode de l'oxytetra cycline selon *Hansson* La croissance journaliere subsequente a ete comparee avec celle des animaux de controle exposes a l'air aux memes pressions pendant les memes périodes L'aspiration d'oxygene semble accélérer la croissance de 2 pour cent pendant la journee du traitement Elle est suivie ensuite par une decelération de 7 pour cent le jour qui suit le traitement Les résultats sont discutes il est porte une appreciation sur le mecanisme en jeu et il est donne un aperçu sur la poursuite des travaux

ZUSAMMENFASSUNG

Aus klinischen Erfahrungen und experimentellen Untersuchungen ist es gut bekannt dass das Langenwachstum der Knochen durch gewisse endzundliche Zustande sowie durch venose Stauung und arterio venosen Shunt beschleunigt werden kann

Um ausfindig zu machen ob diese Anregung durch arterielle Hyperamie oder durch venose Stauung verursacht sei wurden junge Kaninchen einer reinen Sauerstoffatmung unter dem Druck von einer und von zwei Atmosphären wahrend 2 + 2 + 2 Stunden eines einzigen Tages exponiert Die Wachstumsschnelligkeit der proximalen tibialen Epiphysenplatte wurde durch Oxytetracyklin Labelling ad mod *Hansson* studiert

Der beobachtete tagliche Knochenwuchs wurde mit dem Knochenwuchs von Vergleichstieren die Luft des gleichen Druckes und wahrend der gleichen Zeit exponiert worden waren verglichen

Die reine Sauerstoffatmung gab wahrend des Tages der Behandlung eine Beschleunigung des Wachstums von 2 Prozent und eine Verzogerung des Wachstums von 7 Prozent am folgenden Tage

Die Ergebnisse wurden diskutiert der Mechanismus beurteilt und der Plan der zukunftigen Arbeit besprochen

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A COMPARATIVE EXPERIMENTAL STUDY ON TRANSPLANTATION OF AUTOGENOUS AND HOMOGENOUS TENDON TISSUE

By

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Received 8 VI 66

Regeneration and transplantation of tendon tissue have been subject for numerous investigations Nevertheless it is still much discussed in literature whether a true regeneration occurs or the tendon defect is replaced by ordinary scar being in its structure similar to tendon tissue The supporters of the first opinion consider the regeneration to be effected by a tenoblast proliferation from the cut ends of the tendon itself (*Seggel* 1903 *Garlock* 1927 *Stewart* 1936 *Voronin* 1954 *Amosova* 1958) Other authors consider the tendon tissue to be high differentiated and consequently unable for a true regeneration According to them the regeneration arises mainly from the sheats of the tendon stumps by cicatrisation (*Adams* 1860 *Bellow* 1883 *Schwar* 1922 *Tomilova* 1927 *Krivorotov* 1936 *Nikolaev* 1937 *Rosov* 1952 *Skoog & Persson* 1954 *Polen a* 1962)

Mason & Shearon (1932) *Flynn and coll* (1962) and others are of the opinion that union is first effected by proliferation of the sheaths tissues and after the 4th or 5th day—by proliferation of stumps tenoblasts which penetrate into the callus

Not less is the controversy about the fate of the tendon transplant According to the opinion of some authors the autogenous tendon transplant remains alive with the possible exception of the central areas in thicker transplants and showes tenoblastic proliferation (*Garlock* 1927 *Mason & Shearon* 1932 *Peer* 1955 *Lindsay & McDougall* 1961 *Cordrey and coll* 1963) *Lewis & Davis* (1911) considered the fresh homogenous tendon transplant taken as a whole to remain alive

Other group of authors holds that the tendon transplant—either autogenous or homogenous—undergo necrosis and act solely as a strut for ingrowing cells from the host tissues (*Neuhof* 1923 *Teneff & Fonda*

1953 *Slooq & Persson* 1954 *Flynn and coll* 1960, 1962, *Dimoff and coll* 1962, *Degliareva & Lavrishtcheva* 1962 *Herzog* 1963, *Andreeff & Dimoff* 1965)

With the present work we had the task to investigate the possible difference in healing of fresh autogenous tendon transplants and homogenous tendon transplants preserved by means of different methods

MATERIAL AND METHODS

For our experiments we used calcaneus tendon of rabbit because in its anatomical arrangement it resembles the true synovial tendons in man (*Nisbet* 1960)

Thirty seven rabbits were operated For evaluation of the obtained results we took 31 out from that number The experiments were divided into 4 series In the first series in seven animals a segment of soleus tendon was excised turned round and resutured end to end with black silk Sutagor 000 placed *in figure* of eight fashion

After the operation the leg was immobilised for two weeks in a plaster extending to the groin

In the other series were used three types of homogenous tendon transplants which were sutured under moderate tension in the same way into the gap produced by excising a segment of soleus tendon of two three centimeters In 12 rabbits were used homogenous tendon transplants preserved by means of the method we have already reported with proteine hydrolizate at +4 C in the course of 30 90 days In 9 rabbits were used homogenous tendon transplants preserved in the course of 30 84 days by refrigeration at —25 C in 20 per cent Glycerin Ringer s solution In 9 rabbits were used freeze dried homogenous tendon transplants The residual moisture of these transplants was defined to be 2 per cent

Successively after the 1th 2nd 3rd 4th 5th 6th and 7th week after the operation soleus tendon and its transplant were revealed After local examination the whole transplant together with the adjacent ends of soleus tendon and the sheaths were removed and fixed in 10 per cent neutral formaline for morphological examination Classical and histochemical methods were applied as follows for collagen contents (Haematoxylin eosine and Ecrofuxine) for elastic fibres (Orseine) for mucopolysaccharides (Toloudin blau and Periodic Acid Schiff reaction) and for nucleine acids (Acridine orange)

RESULTS

Finally in all experiments the continuity of tendon and transplant was restored and since the 5th week on the animals were able to use their leg freely hopping and rising themselves to it

The reparative processes which have been observed were almost identical and therefore we shall consider all of them together noting the difference in *the corresponding places*

At the end of the first week the stumps sheaths and the tissues round the transplant seemed to be hyperemic Round the joints there were



Figure 1 Homogenous tendon transplant preserved in proteine hydrolysate at the end of the 3rd week after transplantation into the gap of soleus tendon The transplant is completely integrated with the stumps There is a disordered capillary net round the stumps and the transplant

slight adhesions which were easily separated from them Such adhesions were not to be found in the freeze dried homogenous tendon transplants The mesotenonium was healed to the transplant The transplant appeared shiny and slightly oedematous like the stumps as well but well defined from them At the second week there was moderate hyperemia and adhesions round the stumps and transplants and slight adhesions appeared round the freeze dried homogenous tendon transplant The joints seemed to be well healed At the end of the third week the adhesions increased and there was a disordered capillary net The transplant was completely integrated with the stumps the latter being generally thickened (Figure 1) At the fourth week the capillary net round the transplant and the stumps decreases The next week the capillary net had almost a normal appearance and there was longitudinal orientation of the vessels The adhesions were slighter and they did not disturb the normal function of the whole tendon The transplant was defined only by the silk sutures At the end of the 7th week round the stumps and transplant there were found only slight adhesions

Morphological changes The morphological changes were fully identical in all the 4 series of experiments The difference as much as it existed was exceptionally of quantitative character

For better distinctness and clearness of our description the evaluation of the essential changes is reflected in Table 1

During the first week necrosis appears in all tendon transplants The necrotic changes are demonstrated by kariopicnosis kariolysis and

Table 1 1 Fresh Autogenous Tendon Transplants 2 Homogenous Tendon Transplants Preserved in Proteine Hydrolysate at +4 C (by the Method of the Authors) 3 Homogenous Tendon Transplants Preserved by Refrigeration at —25 C in 20 per cent Glycerin Ringer's Solution 4 Homogenous Lyophilised Tendon Transplants

Morphological Changes	Experimental Series	Time Elapsed from Transplantation (in Weeks) 1	2	3	4	5	6	7
Ischemic Necrosis of Transplant	1	+++++	+++++	++++	+++	++	+	—
	2	+++++	+++++	++++	+++	++	++	—
	3	+++++	+++++	++++	++++	+++	+++	+
	4	+++++	+++++	+++++	++++	+++	+++	++
Paratenon and Stumps Capillary Proliferation	1	++++	++++	++++	++++	++	+	—
	2	+++	++++	++++	++++	++	++	+
	3	++	+++	++++	++++	+++	++	++
	4	+	++	+++	++++	+++	+++	++
Paratenon and Stumps Fibroblastic Proliferation	1	+++	++++	+++	+++	++	+	—
	2	+++	++++	+++	+++	+++	+	—
	3	++	++++	+++	++++	++	++	—
	4	++	+++	+++	++++	+++	++	—
Capillary and Fibroblastic Proliferation in Transplant	1	++	+++	+++	++++	++++	+++	++
	2	+	++	++++	++++	++++	+++	+++
	3	+	+	++	+++	++++	++++	+++
	4	±	+	+	+++	++++	+++	+++
Organisation of Transplant	1	+	++	+++	+++	++++	+++±	+++
	2	—	+	++	+++	++++	++++	++++
	3	—	—	+	++	+++	++++	+++
	4	—	—	—	++	+++	++++	+++
Capillary Reduction and Collagenisation of Transplant	1	—	—	—	+	++	+++	++++
	2	—	—	—	—	+	++	+++
	3	—	—	—	—	—	++	++
	4	—	—	—	±	+	++	++



Figure 2 Proliferation of capillaries in the necrotic homogenous lyophilised tendon transplant on the 5th day after transplantation Reaction for sour phosphatasis (× 100)

by changes in the colorific properties of the collagenous fibres of the ground substance

Simultaneously with that the reparative processes develop as well They begin with exudation and capillary and fibroblastic proliferation of the paratenoneum and stumps The granulation tissue consisting of fibroblasts capillaries and the fluid and cells of the exudate surround the stumps and the transplant quickly and fill in the gaps between them The newly formed granulation tissue penetrates into the necrotic transplant

Capillary proliferation most manifestated was established in the autogenous tendon transplants during the first week Vascular response of such a character was found in the homogenous tendon transplants of the 2nd series at the end of the second week while in the others—at the end of the 3rd and 4th week Since the 5th week on this superficial capillary proliferation begins to decrease in the autogenous tendon transplants as well as in the homogenous tendon transplants preserved in hydrolizate solution while in the homogenous tendon transplants of the 3rd and 4th series—since the 6th or 7th week on

Here we must note that capillary vessels penetrating into the periphery of the transplant were found also in the freeze dried homogenous tendon transplants even during the first week (Figure 2)

A fibroblastic proliferation develops parallelly with the capillary proliferation Some perivasal muffs of fibroblasts orientated longitudinally were found still during the first week in the granulation tissue round the stumps and autogenous tendon transplant as well as in the homo

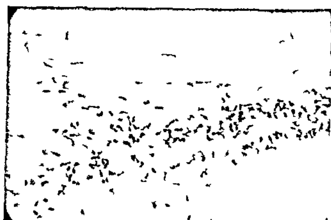


Figure 3. *Necrotic region in an organized homogenous tendon transplant of the 5th week. Colouring—a combined reaction for sour mucopolysaccharides and for desoxyribonucleine acide (× 100).*

genous tendon transplants of the 2nd series. This reaction was less manifestated in the other types homogenous tendon transplants. It begins to decrease since the 3–5th week on.

Concerning the capillary and fibroblastic proliferation in the transplant it develops considerably slowlier. It is less manifestated at the end and superficial layers of the autogenous tendon transplant during the first week. In the homogenous tendon transplants preserved in hydrolizate solution and by means of freezing it begins at the end of the 1st–2nd week while in the freeze dried homogenous tendon transplants —still later (since the 3rd week).

The process of organisation of the transplant begins earliest in the 1st and 2nd series and some later in the frozen and freeze dried homogenous tendon transplants. In some transplants—autogenous and homogenous as well—acellular parts of the necrotic changed transplant different in their size remain among the organized tissue (Figure 3).

Reduction of the small vessels and differently expressed collagenous formation was observed in the granulation tissue between the 4th and 7th week. Bundles of fibrous tissue with collagenous fibres orientated longitudinally are formed during that period. The richness of cells elements decreases gradually and the transplant gets the appearance of a connective tissue cicatrice. The quantity of collagenous fibres orientated longitudinally increases conversely proportionally to the reduction of the proliferated capillaries. Since the 6th–7th week *on the autogenous* tendon transplants receive the morphological appearance of tendon tissue which differs from the normal tendon only by its greater quan-



Figure 3 Vessels in a collagenized autogenous tendon transplant at the end of the 6th week Colouring—Haematoxyline eosine (× 100)

tity of vessels (Figure 4) This process in the homogenous tendon transplants develops slowlier The slowliest one is in the frozen and freeze dried homogenous tendon transplants

DISCUSSION

The results obtained from our comparative study on fresh autogenous tendon transplants and homogenous tendon transplants preserved by means of different methods confirm the opinion that their healing runs principally in one and the same way Our former studies (1962 1965) and the present ones as well as those of *Skoog & Persson Flynn and coll Degtiareva & Lavrishtcheva Herzog and others* prove that necrotic changes appear in the transplanted autogenous and homogenous tendon tissue manifestated by necrobiotic and necrotic changes of the cell elements and of the ground substance of the tendon tissue These changes advance almost in the same terms Tenoblastic proliferation as mentioned by *Mason & Shearon Peer Lindsay and others* was not established in anyone of the transplants That makes us to consider the autogenous as well as the homogenous tendon transplants to play the role only of a bridge through which ingrow the vessels and fibroblasts from the surrounding tissue and stumps of the host

There is no essential difference between the reparative processes in the transplanted autogenous and homogenous tendon tissue The existing difference refers to the terms of appearance and termination of the reparative processes A more precise difference exists between autogenous and homogenous tendon transplants preserved by means

of different methods. The homogenous tendon transplants preserved in hydrolizate solution stand closest to the autogenous tendon transplants.

SUMMARY

The authors have carried out comparative experimental studies on the calcaneus tendon in rabbits in which they have transplanted fresh autogenous tendon tissue and homogenous tendon tissue preserved by means of different methods: in hydrolizate solution at +4° C (a methed of the authors), in 20 per cent Glycerin-Ringer's solution at —20° C and by freeze-drying. The transplants were examined every week in the course of seven weeks. Ordinary and histochemical methods were used.

It has been established that as the autogenous also the homogenous tendon transplants heal with the stumps well and serve as a bridge through which ingrow the vessels and fibroblasts from the surrounding tissues and stumps. Finally the tendon transplant turns into a scar which receives the morphological and functional features of a mature tendon. Only some quantitative difference was established in the regenerative processes between the autogenous and homogenous tendon transplants. The homogenous tendon transplants preserved by means of the authors' method stand nearest to the autogenous tendon transplants.

RESUME

Les auteurs ont procede a des etudes experimentales comparatives sur le tendon d'Achille chez des lapins auxquels ils avaient transplante du tissu tendineux autogene frais et du tissu tendineux homogene conserve au moyen de differentes methodes: dans une solution hydrolysee a +4° C (methode des auteurs), dans une solution de Ringer de 20 pour cent de glycerine a moins —20° C et par lyophilisation. Les greffes ont ete examinees chaque semaine pendant sept semaines. Les methodes ordinaires et histochimiques ont ete utilisees.

Il a ete etabli que comme les autogreffes les homogreffes des tendons reussient aussi bien et servent comme un pont a travers lequel poussent les vaisseaux et les fibroblastes des tissus environnants et meme comme par des bouts de tendon sectionne. Finalement le tendon transplante se transforme en cicatrice qui a les aspects morphologiques et fonctionnels d'un tendon arrive a maturite. Il n'a pu etre etabli qu'une difference quantitative dans le processus de regeneration entre les trans

plants de tendons autogenes et homogènes Les homogreffes des tendons conservés par la méthode des auteurs se rapprochent le plus aux autogreffes des tendons

ZUSAMMENFASSUNG

Die Verfasser haben vergleichende experimentelle Studien an der Calcaneussehne von Kaninchen ausgeführt bei denen sie frisches autologenes Sehnengewebe und mittels verschiedener Methoden konserviertes homologenes Sehnengewebe verpflantzt haben In Hydrolysatlosung bei +4 C (eine Methode der Verfasser) in 20 Prozent Glycerin Ringerlosung bei —20 C und mittels Gefrierungs Trocknung Die Transplantate wurden jede Woche im Laufe von sieben Wochen untersucht Gewohnliche und histochemische Methoden wurden angewandt

Es wurde festgestellt dass sowohl die autologenen als auch die homologenen Sehnentransplantate mit dem Stumpfen gut zusammenheilen und als Brucke durch welche die Gefasse und Fibroblasten des umgebenden Gewebes und der Stumpfe durchwuchern dienen Schliesslich verwandelt sich das Sehnentransplantat in eine Narbe die die morphologischen und funktionellen Zeichen einer reifen Sehne erhalt Nur einige quantitative Verschiedenheiten hinsichtlich der regenerativen Prozesse zwischen autologenen und homologenen Sehnentransplantaten wurden festgestellt Die mittels der Methode der Verfasser konservierten homologenen Sehnentransplantate nahern sich in ihrem Verhalten am meisten der autologenen Sehnentransplantaten

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THE EFFECT OF ORIENTATION ON SOME MECHANICAL PROPERTIES OF FEMORAL CORTICAL SPECIMENS

By

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Received 4 XI 66

INTRODUCTION

Since Rauber in 1876 revealed different moduli of elasticity in longitudinal and transverse sections of cortical bone attention has been paid to the way in which collagen fibers in bone are disposed This information was a matter of controversy after the classical work of Gebhardt and Weindenreich had been published They concluded that the fribrillar structures of human bone tissue was an arrangement of lamellae of alternating longitudinal and circumferential fibrils organized in the longitudinal axis of the Haversian system Recently Smith (1960) re-examined the subject and his findings were in conformity with their interpretation *Maj & Toajari* (1937 1938) in a series of papers demonstrated that compact bone tissue of adults revealed three definitive axes of orientation correlated with the cylindrical coordinates They showed that the load required to fracture the specimen longitudinally to the long axis of bone was three times greater than that for specimens cut tangentially to the axis and six times greater than that of specimens cut radially to the axis The tangentially cut specimens were about twice as strong as radially cut specimens They concluded that the resistance of compact bone to bending failure is proportional to the number of collagen fibers present in the plane of section of the bone and that characteristic mechanical

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anisotropy of bone is the result of the distribution and direction of collagen fibers. *Dempster & Liddicoat* (1952) tested both wet and dry specimens and showed *that cortical bone was significantly stronger* longitudinally than it was in either the tangential or the radial direction with no significant differences detectable between radial and tangential compression loads.

In this laboratory the mechanical properties of cortical bone have been *reviewed recently (Sedlin 1965, Sedlin & Hirsch 1966) and an* analysis of basic factors that control the physical properties was presented. It was intended to develop a model in which the behaviour of bone could be explained in mathematical terms.

Since it is generally agreed that the fiber arrangement is functionally important, *the present study was undertaken to determine how the* variability in direction of fibers in bone could influence its mechanical properties. Cortical specimens from human femurs were cut at 10 degrees increments. The first was made parallel to the longitudinal axis of the shaft of the femur and the last was cut at 90 degrees to that axis. The samples were *subjected to bending tests and the slope* residual deformation and energy dissipated was recorded and calculated.

MATERIAL AND METHODS

This study was based upon 140 samples of human femoral diaphysis obtained at the time of routine post mortem examination of 12 adult subjects. The ages ranged from 30 to 74 years and both sexes were included. Many of the specimens were taken from patients who were at bed rest for varying periods of time prior to death.

The segments of femoral diaphysis were approximately *15 cm long* and were *taken* 5 cm distal to the base of the lesser trochanter. After removal from the body they were prepared immediately or stored at −30° until such time as they could be prepared. *The method of preparation and testing consisted of the following steps.*

The medial and posterior surfaces of the diaphyseal specimens were ground under cold water using water proof silicon carbide paper until the surfaces were per*pendicular to each other*.

Each specimen was then sectioned in its long axis using a band saw converted to the specifications outlined by *Bush* (19[illegible]) utilizing constant irrigation of the *specimen with cold water*. These new surfaces were ground until smooth.

The medial segment of the shaft was fixed, a protractor applied and strips 10 mm broad were sectioned at intervals of 10 degrees in relation to the longitudinal axis of the shaft from 0 to 90 degrees. It was usually possible to obtain 10 strips at different angles from each specimen. These were labelled accordingly and placed in Ringer solution.

To establish whether there was any significant difference between the lateral and medial segments and the superior and inferior portions all cases were compared. In 8 cases two samples were cut from the lateral segment and compared

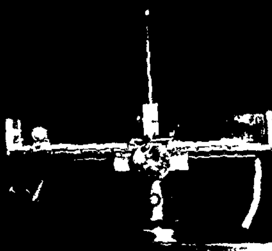


Figure 1 A specimen is being bent as an end supported center loaded beam

with those taken from the medial segment The first was cut at 90 *degrees from* the proximal shaft and the second was cut at 0 degree from the distal To evaluate the superior and inferior portion a similar comparison was made in four cases *The lateral segment* was sectioned superiorly into two strips one at 90 degrees and the other a 0 degree The same was done in the inferior portion

Reduction of the segments to test size was achieved with a special tool by grinding under constant cold water drip using water proof silicon carbide paper as described by *Sedlin & Hirsch* (1966)

The size of the final specimens obtained was 20 mm 2 mm and 1 mm After preparation the specimens were measured using a friction release micrometer accurate to 0 05 mm All specimens with more than 1 per cent discrepancy in size were discarded or reworked After measurements were completed the specimens were placed in Ringer's solution and stored at −30 C until tested

Tests were performed on an Instron TT BM floor model tensile test machine calibrated to an accuracy of ± 0 5 per cent

Only bending tests were used in this study (Figure 1) The specimen was placed as a centrally loaded simple support beam with a support length of 18 mm It was progressively *loaded and unloaded* by means of a special loading head while submerged in Ringer's solution at room temperature (21 C ± 1) The test machine was programmed to cycle between zero load and 50 per cent full scale Two tests were performed on each specimen with a two minute interval allowed between tests The position of the *specimen* was not changed between loads The full scales were 0 100 and 0 250 kilopond at a speed of 0 02 cm per minute

The maximum deformation the residual deformation and the energy dissipated in each cycle test was measured The slope of each curve was calculated as the

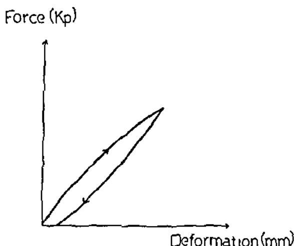


Figure 2 Load deflection curves produced by loading and unloading The maximal deformation at the top of the curve and the residual deformation at zero stress in mm The area between the curves represents the energy lost during the cycle of deformation

quotient of maximum load (P) and maximum deformation (α) The area of the curves was measured by planimetry or geometrically

Standard statistical methods were utilized in evaluating results

ANALYSIS OF RESULTS

The central bending test gave different load deflection curves for increasing and decreasing loads These differences were correlated with the longitudinal axis of the shaft In all tests a loop was described These were not geometrically identical but the findings were quite similar

During loading the curve ascends while the deformation increases up to the maximum force applied When unloaded a descending curve is obtained as the bone tends to return to its previous form (Figure 2) The area between these curves represents the energy lost during the cycle of deformation The distance between these lines at zero stress is the residual deformation On retesting the specimens after a two minute interval using a different force it was found that the relation between load and deformation was identical

The results are summarized in Table 1 2 and 3 There is a relationship between the physical properties of bone tissue and the orientation in which the bone strips were cut

The figures in Table 1 where forces of 0 100 and 0 250 Kp were used show that the stiffness of bone decreases progressively from 0 to 90

degrees The differences between the values for the slope decrease progressively for each ten degrees Figures 3 and 4 demonstrate this tendency to be a straight line relationship

Table 1 Medial samples from femoral diaphysis slope (P/a)

Number of samples	Specimen cut at angle of	Average for 0 100 kp	Standard error	Average for 0 250 kp	Standard error
12	0	174	6	179	5
7	10	173	6	169	12
7	20	154	10	165	9
12	30	149	7	153	8
12	40	134	5	136	4
11	50	117	3	116	3
11	60	110	5	109	6
12	70	99	6	96	7
11	80	94	7	88	8
12	90	87	4	7	5

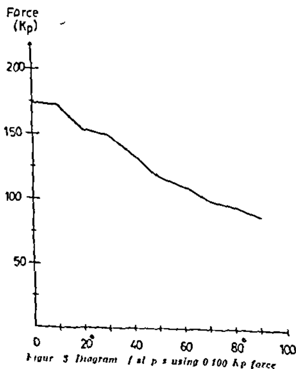


Figure 3 Diagram of slopes using 0 100 Kp force

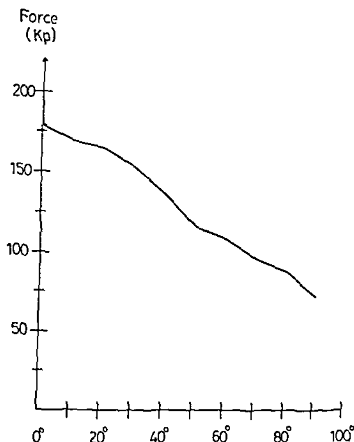


Figure 4 Diagram of slopes using 0 250 Kp force

Table 2 Residual deformation (mm)

Number of samples	Samples cut at angle of	Average for 0 100 kp	± Standard error	Average for 0 250 kp	± Standard error
12	0	0 04	0 005	0 03	0 00
7	10	0 04	0 008	0 01	0 00[illegible]
7	20	0 03	0 007	0 02	0 00[illegible]
12	30	0 04	0 004	0 03	0 006
12	40	0 04	0 004	0 02	0 007
11	50	0 04	0 007	0 04	0 012
11	60	0 03	0 004	0 06	0 019
12	70	0 02	0 004	0 13	0 04
11	80	0 03	0 008	0 20	0 03
12	90	0 03	0 007	0 32	0 07

The residual deformation is expressed in Table 2. An applied force of 0.100 Kp gives a negligible residual deformation and a curve which is a straight line of variable obliquity for all sections. However when 0.250 Kp is applied the shape of the curve is similar with a small residual deformation up to 60 degress. Beyond this level the stape of the curve shows increasing residual deformation and the entire curve becomes more horizontal approaching the abcissa. The 90 degrees samples show this to extreme. In 3 instances the 80 and 90 degrees samples could not resist the maximum force applied and these specimens were unloaded at the point where the curve became horizontal to avoid failure of the specimens.

Table 3 Energy dissipated (Kp/mm)

Number of samples	Samples cut at angle of	Average for 0.100 Kp	± Standard error	Average for 0.250 Kp	± Standard error
12	0	0.00018	0.00002	0.00029	0.00006
7	10	0.00019	0.00004	0.00023	0.00011
7	20	0.00013	0.00003	0.00032	0.00009
12	30	0.00019	0.00007	0.00023	0.00007
12	40	0.00018	0.00007	0.00021	0.00007
11	50	0.00019	0.00003	0.00053	0.00024
11	60	0.00015	0.00002	0.00136	0.00050
12	70	0.00009	0.00002	0.00448	0.00188
11	80	0.00015	0.00003	0.00704	0.00796
12	90	0.00016	0.00007	0.01109	0.00246

The energy dissipated Table 3 becomes greater as the residual deformation became greater.

Since this study was made on the medial segment of the femur it was important to establish if there were significant differences between the lateral and medial segments and between the superior and inferior sections. The evaluation of the test results by the Student's T test revealed that the slope the residual deformation and the energy dissipated of each curve was not significantly different from the medial segments (Table 4, 5 and 6). The same was true for the superior and inferior sections (Table 7, 8 and 9).

Table 4 Differences between medial and lateral segments slope (Pa)

Number of samples	Samples cut at angle of	Side	Average for 0 100 kp	Student T test	Average for 0 250 kp	Student T test
8	0	Medial	173	not significant	185	
		Lateral	184		189	not significant
8	90	Medial	85		67	
		Lateral	76	not significant	65	not significant

Table 5 Residual deformation (mm)

Number of samples	Samples cut at angle of	Side	Average for 0 100 kp	Student T test	Average for 0 250 kp	Student T test
8	0	Medial	0 07	not significant	0 03	
		Lateral	0 07		0 02	not significant
8	90	Medial	0 07	not significant	0 8	
		Lateral	0 03		1 0	not significant

Table 6 Energy dissipated I (kg/ cm)

Number of sample	Sample cut at angle of	Side	Average for 0 100 kp	Student T test	Average for 0 250 kp	Student T test
8	0	Medial	0 000	not significant	0 0002	not significant
		Lateral	0 007		0 000	
8	90	Medial	0 007		0 01	
		Lateral	0 003	not significant	0 02	not significant

Table 7 Differences between upper and inferior section of the lateral segment of the femur slope (I/a)

Number of samples	Samples cut at angle of	Section	Average for 0 100 kp	Student T test	Average for 0 250 Kp	Student T test
8	0	Superior	170	not significant	131	not significant
		Inferior	184		191	
8	30	Superior	93	not significant	72	not significant
		Inferior	100		91	

Table 8 Residual deformation (mm)

Number of samples	Samples cut at angle of	Section	Average for 0 100 Kp	Student T test	Average for 0 250 Kp	Student T test
8	0	Superior	0 01	not significant	0 02	not significant
		Inferior	0 02		0 02	
8	90	Superior	0 02	not significant	0 2	not significant
		Inferior	0 04		0 4	

Table 9 Energy dissipated (Kp/mm)

Number of samples	Samples cut at angle of	Section	Average for 0 100 Kp	Student T test	Average for 0 250 Kp	Student T test
8	0	Superior	0 00006	not significant	0 0003	not significant
		Inferior	0 00014		0 0003	
8	90	Superior	0 00012	not significant	0 01	not significant
		Inferior	0 00059		0 02	

SUMMARY

It is apparent from earlier investigations that the arrangement of collagen fibers play a basic role in the strength of bone tissue The influence of small changes in direction of fibers on bone strength has not previously been evaluated Our study demonstrates that the stiffness of cortical bone is closely related to the angles of which bone is cut being less stiff as the angle increases in relation to the longitudinal axis of the shaft The residual deformation and the energy dissipated are proportional and vary with the angle

RESUME

Des investigations antérieures ont fait ressortir que l arrangement des fibres collagènes joue un role fondamental pour la force du tissu osseux On n a pas procede anterieurement a une evaluation de l influence que peuvent avoir de petits changements dans la direction des fibres sur la force de l os Notre etude demontre que la rigidite de l os cortical est étroitement liée aux angles selon lesquels l os est coupe Il devient rigide au fur et a mesure de l augmentation de l angle Par rapport a l axe longitudinal du corps de l os la deformation residuelle et l énergie perdue sont proportionnelles a cet angle et varient avec lui

ZUSAMMENFASSUNG

Aus fruheren Untersuchungen geht hervor dass die Anordnung von kollagenen Fasern eine wesentliche Rolle hinsichtlich der Starke von Knochengewebe spielt Der Einfluss von geringen Veranderungen in der Richtung der Fasern auf die Knochenstarke ist vorher nicht bestimmt worden Unsere Untersuchung erweist dass die Steifheit kortikalen Knochens eng mit den Winkeln in Bezug auf die Längsachse des Schaftes unter denen der Knochen geschnitten wird zusammenhangt indem die Steifheit abnimmt wenn der Schneidungswinkel zunimmt Die zuruckbleibende Deformierung und die verschwendete Energie sind proportional und wechseln mit dem Winkel

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Acta orthop. Scandinav. 38, 57–66, 1967

From the Department of Hand Surgery (Head: K. Bang Rasmussen),
Orthopaedic Hospital, Copenhagen, Denmark.

MEGALODACTYLISM

Report of 7 Cases

By

K. RECHNAGEL

Received 2.XI.66

Megalodactylism is a rare and peculiar disease consisting in a grotesque overgrowth of one or more fingers. The overgrowth is present at birth and increases somewhat during childhood, but usually stops at puberty. The abnormal growth comprises all tissues, bones as well as soft tissues, and always appears to be associated with considerable thickening or even tumor formation of the median or ulnar nerve and their branches.

Apparently the increased growth is maximal along an axis, decreasing to both sides of it. This lends the digits a lateral curvature away from the axis (7). As a rule only one or a few fingers are affected, while the others are entirely normal.

The aetiology of the disease is unknown and there are no prophylactic measures. Therefore the treatment has to be restricted to amputations and plastic operations thinning out the hypertrophic soft tissues. In addition, some cases have been treated by epiphysiodesis (3, 6), which has proved a successful check on longitudinal growth, but of course has not reduced the thickness of the giant fingers.

At times there is such pronounced thickening of the median nerve that this has required operation with removal of the tumour, possibly together with the nerve, which is in some cases 1 cm in thickness; the digital nerves may be as thick as a lead pencil. If the nerve is traced proximally, it gradually approaches normal dimensions.

The microscopic appearances of the removed tissue are uncharacteristic. As is apparent from the following case reports, the histological diagnoses are "lipoma", "fibrolipoma" or "lipo-fibroneuroma". The appearances are reminiscent of those described by Dejerine-Sottas

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is hypertrophic neuritis, which, however, is not associated with gigantism. No signs of malignancy have been found.

Other designations of this rare disease also refer to the nerve changes: "elephantiasis nervorum" and "von Recklinghausen type of macrodactylism" (11). However, although the microscopic picture may at times remind of von Recklinghausen's neurofibromatosis, the patients usually do not exhibit the subepidermal neurofibromas characteristic of this disease.

The disease has also been called "macrodystrophia lipomatosa" because of the very ample soft tissues on the fingers and adjacent parts of the hand (8).

The few previous cases have been published mostly one by one (3, 6, 8, 9, 10). In the Departement of Hand Surgery of the Orthopaedic Hospital, Copenhagen, we have collected 6 cases in the course of the past years, which will be reported below together with one case affecting the foot. Some authors (6) have stated that the overgrowth most often affect the long and ring fingers, while others say that the index and long fingers are most often involved (1, 7). The present 6 cases confirm the latter view, as the *index finger* was involved in all 6 cases, the *long finger* in 4, the *thumb* in 2, and the *ring finger* in only 1 case. The little finger was not affected in any case.

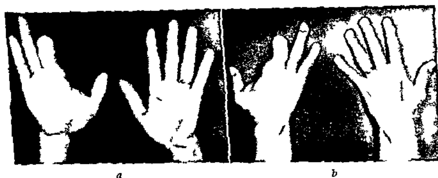
Arterio-venous anastomoses or aneurysms may give rise to some overgrowth, but hardly of this special nature. Arteriography done in Case 3 showed no vascular abnormalities.

No hereditary features were demonstrated. Among the patients' closest relatives there had not been deformities other than varus feet (Case 3). As to some action which may have been operative during foetal life we can only surmise. Regrettably, it was impossible to study this aspect in the reported cases, mainly because the patients were born long before attention was directed at toxic actions during pregnancy. On the basis of the knowledge about the earliest embryological development (4, 12) and in analogy with the contemplations concerning other extremity malformations (5), it is reasonable to *believe that the cause may have been embryological or foetal*.

Giant growth may occur also in sites other than the fingers. As in Case 7 it may involve the toes (*10*), *and it may affect an entire limb (2)*, but the literature also includes description of cases with hemilateral giant growth and hypertrophy of the contralateral cerebral hemisphere (*2*). *In principle this "hemihypertrophy" is similar to the local* changes described in the present paper.



Figures 1 a and b Cas 1 female ag I 16



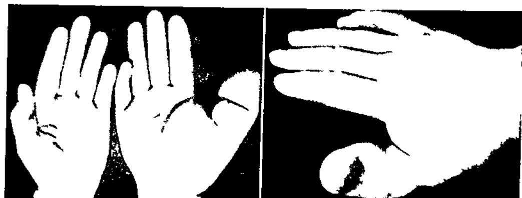
Figu 2 a and b Ca e 1 at 38 years of ag

Of the 7 patients (the case affecting the toes included) 3 were fe males and 4 males All the cases were unilateral

Ca 1

A w m n n w age l 38 with giant gr wth of the ind x and l ng fingers from bi th At the age of 4 years the di tal phalanx of both these fingers had been re m ed t the local h pital She w s r ferred t the Department of Hand Surgery because f thickening of the s ft ti sue on the v lar a pect of the h nd fr m the wri t t the tips f the in lex and long fingers and c n iderable giantism of these finger (Figures 1 a and I)

At th age of 16 she ha l a) op rati n rem ving the greater p rt of the ample s ft ti ue a t tal f 155 g (ro sl the sp cimen l ked like typical l poma Later part f the mi ldle phalange of b th fingers was rem ed Ther aft r the c n diti n remaine l st tion r f r me e r but then she st rted to have increa ing c m plaints due to increa e l gr wth f the s ft tissue mainl in the wel pace between



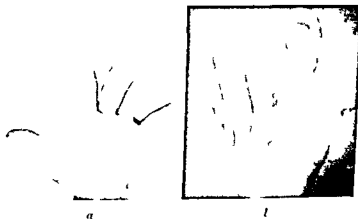
a b

Figures 3 a and b. Case 2, female, aged 20



a b

Figures 4 a and b. Case 2 at 33 years of age

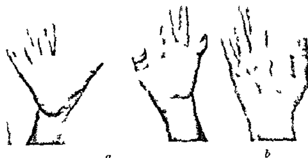


a b

Figures 5 a and b. Case 3, female, aged 10



Figure 6 Cas 3 Operative specimen of the enlarg d median nerie with br inches



a b

I igur s 7 a an l b Case 3 il 8 y urs of aje

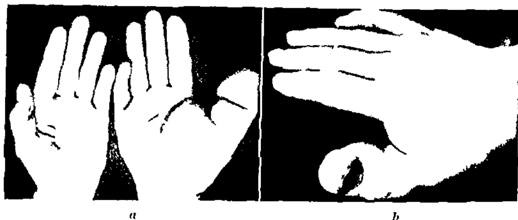
th thuml an l in lex finger Theref re at 38 ears of age he had another opera tion c mpri ing re c ti n f the hy ertr phic median ner e ard *transmeta arpal* mputati n f the in l x finger The median nerve was a thi k as a *thumb the* ligital nerve v re 3 4 mm thick Mi r exam Lipoma

At f ll v up 6 m nths after the o erati n (Figure 7 a and b) *the main c m* plaint apart fr m the c meti a p ct was weakne f the thumb and d ficient p ition There ha l e n n *further gr wth*

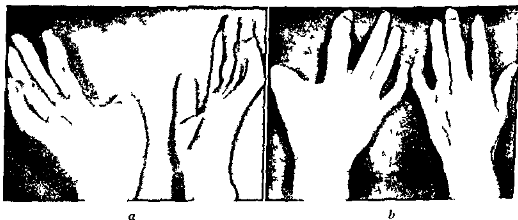
(7

A w man n v age l 33 wh h d from birth had a la ge right thuml which had n hi in r a) in iz At the ge cf 20 th finger h wed the appearance illus trat l in Figur 3 a an l b La tial exci i n cf the increa cd s ft ti sue wa done Th l r n he f th m li n nerve were a thick as l a l pencil the sen rv nerves t th thenar emirence 5 mm thick Large ma es f lipoma infiltrated all muscles ir th wel pa letwe n the thuml an l ind x fing r splitting the mu cle fibres apart A lump as large a l en egg was removed M r exam Lip ma

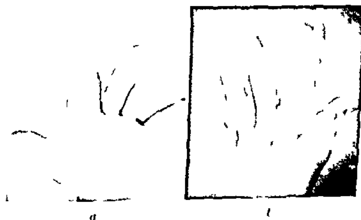
A f w m nth lat r xarticul ti n of the d stal phalanx cf the thuml and thin ning f th s ft tis ues At f ll w up *till thr kening f the s ft ti s ies* in the th nar minen e but du ing the pa t 10 year *there ha l n t* been furthe growth an l the patient leclared th t sh e w quite ati fied (Figures 4 a and b)



Figures 3 a and b. Case 2, female, aged 20



Figures 4 a and b. Case 2, at 33 years of age



Figures a and b. Case 3, female, aged 11



Figures 9 a and b Case 4 at 9½ years of age

(Figures 8 a, b and c) Partial amputation of the index finger was done but later at follow up he had increasing swelling in the palm so that at the age of 6 years he had another operation removing a considerable fatty infiltration with wide spread nerve fibres from the median nerve However there was still slow growth of the soft tissue and at the age of 14 the tumour was removed together with the median nerve which was 1 cm thick at the wrist the digital nerves were 5 6 mm thick After exam Lipo fibroneuroma Yet another operation comprised removal of a couple of neuromas as well as amputation of the index finger and of the distal phalanx of the long finger Now the condition is said to be stationary The long finger which shows ulnar deviation can reach the palm (Figures 9 a and b)

Case 5

A male now aged 21 who had from birth had gigantism of the left index finger and thickening of the soft tissues of the thumb At the age of 5 years he was subjected to operation thinning the thumb which thereafter remained fairly normal but at 14 years of age he was referred because of enlargement of the index finger who e distal phalanx was almost spherical with 45 ulnar deviation This phalanx was amputated but as irregular tender thickening remained at the tip of the stump the middle phalanx was amputated 2 years later

At follow up there was no further growth of the finger but considerable thickening of the soft parts on the volar aspect of the stump No palpable enlargement of the median nerve

Case 6

A ... now 7 years of age had at birth syndactylism of the left long and ring fingers This was repaired on the following day in the local hospital When first seen he was at the age of 7 months he had enormous enlargement of the long and ring finger (Figures 10 a b and c) Exarticulation of the long finger was done At this operation no hypertrophy of the nerve was found Two years later the boy had developed considerable thickening of the soft tissue and he had another operation removing lipomatous masses situated in part intraneurally in the median



a

Figures 8 a, b and c. Case 4, a boy aged 2 years.



b



c

Case 3

A woman now aged 28 who had always had an enormous index finger and some enlargement of the long finger on the left hand. Referred because of thickening of the soft tissue in the left palm and distal part of the forearm when she was 16 years of age (Figures 5 a and b). At operation the tumour was found to consist of the median nerve which was filled with lipoma-like masses. As much as possible of the tissue was removed without injuring the branches of the nerve. Micr. exam.: Fibrolipomatous changes.

A couple of months later the index finger was amputated, and later, when she was 18, the median nerve was excised because the tumour went on growing. The nerve and its branches were found to be enormously thickened, about 3 × 1½ cm in cross section, and the digital nerves were as thick as lead pencils (Figures 6).

At follow up now, when she is 28, she has surprisingly slight complaints on account of the lacking sensibility. The long finger had not grown further (Figure 7 a and b).

Case 4

A male now aged 24 who was seen for the first time at the age of 2 years. There was gigantism of the left index and long fingers which showed lateral deviation



a *b*

Figures 9 a and b Case 4 at 9½ years of age

(Figure 8 a b and c) Partial amputation of the index finger was done but later at follow up he had increasing swelling in the palm so that at the age of 6 years he had another operation removing a considerable fatty infiltration with wide spread nerve fibres from the median nerve However there was still slow growth of the soft tissue and at the age of 14 the tumour was removed together with the median nerve which was 1 cm thick at the wrist the digital nerves were 5 6 mm thick Micr exam Lipo fibroneuroma Yet another operation comprised removal of a couple of neuromas as well as amputation of the index finger and of the distal phalanx of the long finger Now the condition is said to be stationary The long finger which shows ulnar deviation can reach the palm (Figures 9 a and b)

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A couple of months later the index finger was amputated and later when she was 18 the median nerve was excised because the tumour went on growing The nerve and its branches were found to be enormously thickened about $3 \times 1\frac{1}{2}$ cm in cross section and the digital nerves were as thick as lead pencil (Figures 6)

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A male now aged 24 who was seen for the first time at the age of 2 years There was giantism of the left index and long fingers which showed lateral deviation



Figure 12 Case 7 a male aged 24 with megalodactylism affecting the foot

Case 7

A male aged 24 who had from birth had giantism of the right 2nd and 3rd toes both of which are larger than the great toe (*Figure 12*) No definite *thickening* palpable along the course of the nerves If only he has a sufficiently large shoe he has no complaints so we did not feel that any treatment was indicated

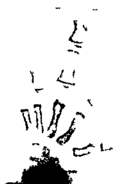
SUMMARY

Seven cases of the rare condition *megalodactylism* are submitted This disease consists in local giant growth affecting one or more fingers or toes comprising all tissues and often associated with considerable thickening of the nerves supplying the area The aetiology is unknown and the histological appearances are uncharacteristic Malignant changes have not been observed

The treatment is restricted to plastic operation *epiphysiodesis* and amputations

RESUMÉ

7 cas de la maladie rare *megalodactylie* sont presentes Il s agit d une croissance gigantesque locale qui *touche un ou* plusieurs doigts ou orteils qui porte sur tous les tissus et qui est souvent accompagnée d un épaississement considérable *des nerfs dans la* partie en question L etiologie de cette maladie est inconnue le tableau histologique n est pas caractéristique Aucune modification maligne n a été observée



a

Figures 10 a b and c Case 6 boy aged 7 months



b



c



a



b

Figures 11 a and b Case 6 at [illegible] year of [illegible]

nerve The common digital nerves to the index long and ring fingers were now almost 1 cm thick Micr exam Connective fatty tissue with fibrous changes

Six months later the patient has tran metacarpal amputation of the ring finger and at follow up the hand was quite good He can use it almost normally and can clench the index and little fingers completely (Figures 11 a and b)



Figure 12 Case 7 a male aged 24 with megalodactylism affecting the foot

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The treatment is restricted to plastic operation epiphysiodesis and amputations

RESUME

7 cas de la maladie rare *megalodactylie* sont presentes Il s agit d une croissance gigantesque locale *qui touche un ou plusieurs doigts ou orteils qui porte sur tous les tissus et qui est souvent accompagnee* d un épaississement *considérable des nerfs dans* la partie en question L étiologie de cette maladie est *inconnue le tableau histologique* n est pas caractéristique Aucune modification maligne n a été observée

Le traitement se borne à des opérations plastiques, épiphysiodèses et amputations.

ZUSAMMENFASSUNG

7 Fälle des seltenen Leidens der *Megalodactylie* werden vorgestellt. Es dreht sich hier um ein örtliches Riesenwachstum, das einen oder mehrere Finger oder Zehen betrifft, alle Gewebe umfasst und von einer bedeutenden Verdickung der Nerven des betroffenen Gebietes begleitet wird. Die Ätiologie ist unbekannt, das histologische Bild uncharakteristisch. Maligne Veränderungen sind nicht vorgekommen.

Die Behandlung schränkt sich auf plastische Operationen, Epiphyseodesen und Amputationen ein.

ACKNOWLEDGEMENT

Thanks are due to *Erna Christensen*, M.D., of the University Institute of Neuropathology, Copenhagen, for examining the histological specimens.

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From the Clinic for Orthopaedics and Traumatology, University Central Hospital, Helsinki (Head: Professor K. E. Kallio)

OPERATIVE TREATMENT OF TORN LIGAMENTS IN INJURIES OF THE KNEE JOINT

By

KAUKO A. SOLONEN & PENTTI ROKKANEN

Received 22.I.67

The stability of the knee joint is a complicated function in which besides bony and cartilaginous structures soft tissues take part, i.e. a number of muscles and their tendons and several ligaments, the most important of which are the cruciate and collateral ligaments, and the joint capsule. The main function of the cruciate ligament is perhaps to act as a guide rope for movements, not as a checkstrap (*Helfet* 1963).

When a ruptured ligament is treated conservatively there is no guarantee of reliable reduction and fixation of the ligamentous ends. When methods of conservative and operative treatment have been experimentally compared it has appeared that healing is quicker and better when apposition and fixation of the ligamentous ends have been carried out operatively (*Clayton & Weir* 1959).

In our hospital acute total ligamentous injuries have in recent years as a rule been repaired surgically. The results of treatment will be presented in the following.

MATERIAL

During the period 19[illegible]8–19[illegible]5 128 total ruptures of the cruciate or collateral ligament were treated operatively. 90 (71 per cent) were followed up for 1 to 8 years after the trauma. Of these cases 71 were recent and 19 old, meaning cases operated on within three weeks or later. The followed patients had had a total of 156 ruptures. The various combinations are shown in Table 1.

Together with ligament ruptures there were fractures of the tibial or femoral condyle in 13 cases. Injuries of the meniscus occurred in 47 patients. In connection with tearing of the lateral collateral ligament the fibular nerve was totally ruptured in two cases. In connection with other ligament ruptures there was total avulsion of the patellar ligament in 4 cases.

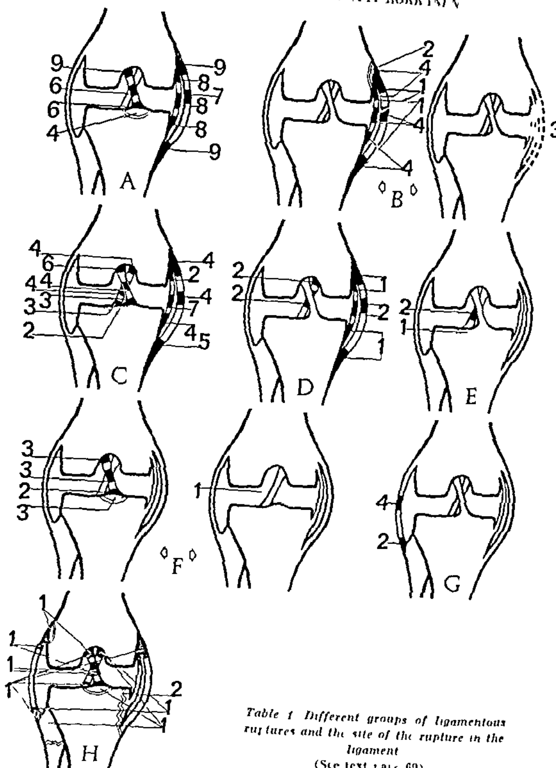


Table 1 Different groups of ligamentous ruptures and the site of the rupture in the ligament

(See text page 69)

The following types of traumata were represented 38 traffic accidents 24 falls 22 injuries in athletics 4 direct blows and 2 open lacerations

Of the patients 65 were males and 25 females 13 of the patients were under 20 years old 39 were 21 to 40 33 were 41 to 60 and 5 over 60 In all patients over 60 the main indication for operative treatment was an intra articular fracture

DIAGNOSIS

Diagnosis was based on clinical examination largely according to *de Palma* (1954) and on plain radiograms Particular attention was paid to abnormal movement as a result of torn ligaments of the knee joint Examination as soon after the trauma as possible was considered to be ideal The diagnosis was often confirmed under anaesthesia immediately before the operation Arthrography or roentgenographic examination under stress were not employed

OPERATION

Operation was carried out on the day of the trauma in 19 cases on the first or second posttraumatic day in 34 cases and within 3 to 11 days in 18 cases 19 old injuries were operated on 3 weeks to 3 years after the trauma (after more than 4 months in 14 out of 19 cases) Operation was carried out under general anaesthesia and the limb was exsanguinated provided that no contraindications existed Ligament ruptures were as a rule sutured with chromic catgut Insertion ruptures and avulsion fractures were fixed with sutures or screws to their freshened sites (Figure 1) In 4 recent cases the ruptured anterior cruciate ligament was reinforced by a distally based fascial graft to act as its core the remnants of the ligament being handled as atraumatically as possible One recent rupture of the medial collateral and anterior cruciate ligaments was repaired by *Hey Groves* (1917 1920) method

For the repair of old tears the following methods among others were employed for the repair of the anterior cruciate ligament Hey Groves method and modifications thereof (*Brantigan and Voshell* 1936 *O Donoghue* 1963) reinsertion of avulsion [illegible]

Table 1

A	Medial collateral and anterior cruciate ligament	25 cases
B	Medial collateral ligament (The site of the rupture could not be determined with certainty in 3 of these cases)	19 "
C	Medial collateral and anterior and posterior cruciate ligament	13 "
D	Medial collateral and posterior cruciate ligament	4
E	Posterior cruciate ligament	7 "
F	Anterior cruciate ligament (In one of these cases the ligament was entirely absent)	12
G	Lateral collateral ligament	6 "
H	Other (combinations)	8 "
	Total	90 cases

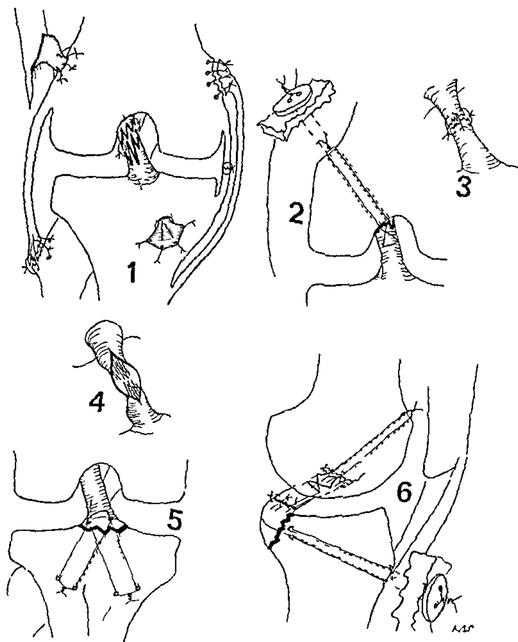


Figure 1. Different types of diagnosed ruptures and the methods used for primary repair.—The torn ligament has already been strenghthened at the primary operation by a graft, the ligamentous tissue nevertheless being preserved as undamaged as possible (1). The most important factors are the correct position and direction of the ligament but not the intraosseous course of the graft or the thread (1, 2, 5). The cruciate ligament was sometimes repaired with thin transligamental sutures but more often with transosseous sutures which could be left or removed (2, 3, 5, 6). A stretched cruciate ligament was torn often totally though subsynovially (4).

for the repair of the medial collateral ligament *Hey Groves* *McMurray Helfets* (1963) *Mauck* (1936) and the reversed Mauck method for the repair of the lateral collateral ligament *Edward's* (1921) method and transplantation of the insertion according to Mauck

Postoperatively the limb was immobilized in slight flexion in a plaster cast usually for 6 to 8 weeks Exercise of the quadriceps muscle was if possible begun on the first postoperative day walking with crutches 1 to 2 weeks after the operation and weight bearing after 3 to 6 weeks Fractures that had occurred simultaneously with ligamentous injuries often influenced the postoperative treatment in particular

RESULTS

When evaluating the end results at follow up we aimed at appraising the result of treatment of the whole knee injury In cases of fracture separate mention will be made of the result of treatment of the ligament involved For the classification of results we have defined excellent good fair or poor results as follows

Excellent Full mobility and stability no pain during activity only slight muscular atrophy of the thigh

Table 9 Results of treatment of recent ligamentous injuries which were not accompanied by fracture of condyles

Ligamentous injury	Total	Excellent	Good	Fair	Poor
Medial collateral and anterior cruciate	21	5	7	7	2
Medial collateral	10	4	2	4	–
Medial collateral and anterior and posterior cruciate	10	3	3	2	2
Medial collateral and posterior cruciate	4	1	–	–	3
Posterior cruciate	3	–	1	–	2
Anterior cruciate	3	2	–	–	1
Lateral collateral	2	–	–	1	1
Other	5	1	1	2	1
Total	58	16	14	16	12
Per cent	100	28	24	28	20

Good Full extension range of flexion at least 110 degrees or not more than 20 degrees less than in the other limb no pain during activity not more than 2 cm difference in the circumference of the

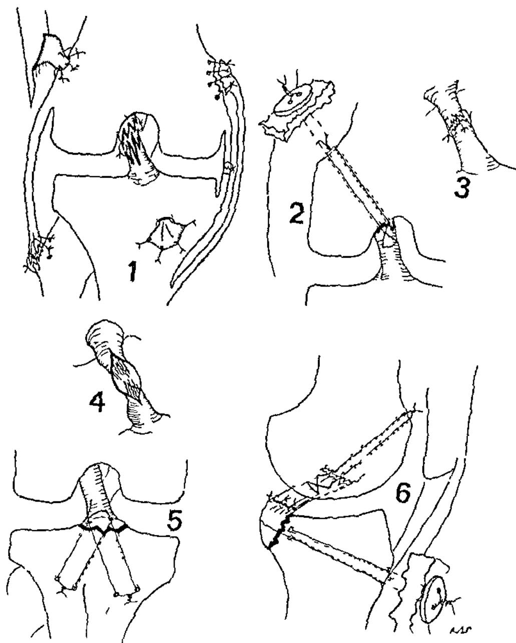


Figure 1 *Different types of diagnosed ruptures and the methods used for primary repair —The torn ligament has already been strenghthened at the primary operation by a graft the ligamentous tissue nevertheless being preserved as undamaged as possible (1) The most important factors are the correct position and direction of the ligament but not the intraosseous course of the graft or the thread (1 2 6) The cruciate ligament was sometimes repaired with thin transligamental sutures but more often with transosseous sutures which could be left or removed (2 3 5 6) A stretched cruciate ligament was torn often totally though subsynovially (4)*

in patients over 50 who constituted one fifth of the series than in young patients We concluded that it was the severity of the injury not the patient s age which had influenced the end result

When studying *the time of operation* and the end results we found that a good or excellent result was obtained in 40 per cent of cases operated upon on the the day of the injury in 65 per cent of cases operated upon on the first or second posttraumatic day and in 55 per cent of cases operated upon on the third to eleventh posttraumatic day

Table 4 Involvement of meniscus in ligamentous injury

Ligamentous injury	Number of cases			
	Involvement of medial meniscus	Involvement of lateral meniscus	Involvement of both menisci	Total
Medial collateral and anterior cruciate	13	1	2	16
Medial collateral	2	2	–	4
Medial collateral and anterior and posterior cruciate	4	4	2	10
Medial collateral and posterior cruciate	2	–	1	3
Anterior cruciate	3	1	1	5
Lateral collateral	1	3	–	4
Other	3	2	–	5
Total	28	13	6	47

There were 53 injuries of the meniscus *both menisci being injured* in 6 cases (Table 4) In connection with old ligamentous injuries there was tearing of 6 medial and 2 lateral menisci Injury to the meniscus was commonest in the group of rupture of the medial collateral anterior cruciate and posterior cruciate ligaments (10/13) In two of these cases both menisci were ruptured Only those injuries of the meniscus which required surgical repair were taken into account under this heading In 31 cases the meniscus had to be removed In 17 cases the meniscus detached to a varying degree was sutured to its site In 2 cases a small pedunculated tag of the meniscus was excised In no case in which a partly detached meniscus was sutured to its site did this meniscus subsequently cause any distress The results of treatment of

thighs subjectively stable and objectively slight insufficiency of one ligament only.

Fair. Insufficiency of extension not exceeding 10 degrees, flexion to at least a right angle, pain at sport or other such exertion, subjectively stable but slight objective instability of 1 to 2 ligaments was accepted.

Poor. Poorer than the above.

Table 3. Results of treatment of old ligamentous injuries

Ligamentous injury	Total	Excellent	Good	Fair	Poor
Medial collateral and anterior cruciate	3	1	–	1	1
Medial collateral	3	1	1	1	–
Anterior cruciate	9	1	3	3	2
Lateral collateral	2	–	–	1	1
Other	2	–	1	–	1
Total	19	3	5	6	5
Per cent	100	16	26	32	26

The results of treatment of recent and old ligamentous injuries are given in Tables 2 and 3. When these results are compared, we find that there were relatively more excellent results and fewer poor results among the recent injuries than among the old injuries, while the number of good and fair results was largely the same. When recent mono- and multiligamentous injuries are compared, we find excellent to good results in 50 per cent of the cases of monoligamentous and in 52 per cent of multiligamentous injuries. Multiligamentous injuries are often accompanied by other injuries (fractures, ruptured menisci).

In multiligamentous injuries no specification of the ligaments has been made. It seems, however, that in repair of a detached ligamentous insertion a better result was obtained because the procedure was technically easier and continuity of the ligament was preserved. At all events in avulsion fracture of the insertion a good result was obtained in all but one case. There were 8 cases of avulsion fracture of the distal insertion of the anterior cruciate ligament and 1 of the posterior cruciate ligament, 2 cases of fracture of the proximal and 2 of the distal insertion of the medial collateral ligament and 1 of avulsion fracture of the distal insertion of the lateral collateral ligament.

There was a relatively greater number of multiligamentous injuries

or its infrapatellar branch was observed in one third of the patients and gave rise to inconvenience many years after the operation

Causes of Poor Results

1 Faulty diagnostics In at least 6 cases some ligamentous injury had escaped diagnosis

2 Faulty treatment 6 cases were found in which the injury had been considered to be mere straining of the anterior cruciate ligament which was consequently left unrepaired It should be mentioned that in 4 cases the synovial membrane of the allegedly strained anterior cruciate ligament was opened and the ligament found to be completely torn whereupon it was successfully repaired In 4 cases a diagnosed injury of the posterior cruciate ligament was left unrepaired and in all of them the result was poor In 9 cases persistent ligamentous insufficiency was observed as a result of unsuccessful surgery

3 Faulty postoperative treatment There was markedly reduced mobility of the knee joint in 4 cases the reason in at least 3 cases being the patient s inactivity

4 2 cases of wound infection One of these cases was a multiligamentous injury in which infection led to marked reduction of the mobility in the knee joint The second case was one of old ligamentous injury which had been operated on for the same reason four times at some other hospital

DISCUSSION

On the basis of the present study we could establish that an excellent or good result was obtained by operative treatment in 52 per cent of cases of recent injuries of ligaments and in 42 per cent of cases of old injuries of ligaments In ligamentous injuries accompanying fracture of a condyle the result of treatment was impaired by deformity or reduced mobility as a result of the fracture The extent of the surgically treated injuries is illustrated among other things by the fact that 60/90 injuries were multiligamentous and that in more than half the cases the meniscus was involved as well

The principal causes of poor results were faulty diagnosis and treatment A contributory factor was that treatment was undertaken by numerous surgeons of varying experience The patient s cooperation in the postoperative treatment also proved to be of importance

To improve the diagnostics a thorough knowledge of the anatomy

knee injuries with involvement of the meniscus were no worse than when the meniscus was intact.

The results of treatment of ligamentous injuries associated with fracture of the condyle are seen in Table 5. These cases do not include avulsion fractures of the insertions or extra-articular fractures of the same limb. Besides the fracture mentioned in the table there was sometimes fracture of the tibial spine or of the neck of the fibula or insertion fracture of the patellar ligament, fracture of the patella, etc. The total result is aggravated by the deformity or reduced mobility caused by the fracture. In 3 cases the ligamentous result alone was excellent and in the remaining cases less than excellent.

Table 5. Results of treatment of ligamentous injuries associated with fracture of condyles

Ligamentous injury	Fractured condyle	Total	Excellent	Good	Fair	Poor
Medial collateral and anterior cruciate	Medial tibial	1	–	–	–	1
Medial collateral	Lateral tibial	6		3	2	1
Medial collateral and anterior and	Medial tibial	1	–	1	–	–
posterior cruciate	Lateral femoral	2	–	–	2	–
Lateral collateral	Both tibial	2	–	2	–	–
Anterior and posterior cruciate	Lateral tibial and femoral	1				1
Total		13	–	6	4	3

In 22 cases out of the 86 in which rotation of the knee joint could be measured with the joint flexed at 90 degrees, this movement had changed after operation. Where there was instability of the medial collateral ligament, in some cases with instability of the anterior cruciate ligament as well, the range of rotation in the knee joint had increased in 14 cases. When the medial collateral ligament was taut, the range of rotation was reduced in 8 cases.

Muscular atrophy of the thigh was measurable in half the cases. It was even subjectively demonstrable many years after successful treatment with good end results, also in young and active persons. Disturbed sensibility of the skin after operative damage to the saphenous nerve

repaired Moreover the satisfactory results obtained in many extensive injuries such as the two cases of dislocation of the knee (Figure 2) speak in favour of operative treatment It is evident that in such cases the very fact that the injury is extensive contributes not only to a correct diagnosis but also to adequate repair of the injury

An analysis of the poor results shows that all totally ruptured ligaments should be repaired When for various reasons a ruptured ligament was left unrepaired the end result was poor except in cases of undislocated avulsion of ligamentous insertions The importance of the posterior cruciate ligament was underestimated In 4 cases rupture of this ligament had been left unrepaired and in each case the result was poor There was a spontaneous "drawer sign backwards and one of these patients himself suggested a brace To what extent injuries to other posterior supporting elements were of significance in these cases cannot be judged from the operative reports It may perhaps be assumed that the synchronism and interaction of ligaments and muscles are disturbed if some part is not functioning It seems not unlikely that the absence of one important element would provoke disturbance of the others The fact that patients who had initially been treated conservatively subsequently sought treatment also speaks in favour of operative treatment in the acute stage

Operation carried out on the day of the accident is an emergency procedure On the subsequent days the conditions are more favourable The results indicate that emergency operations are not as a rule unavoidable but that operation should preferably be carried out during the next few days— after careful examination and under adequate operative conditions

Although in the present series the results of operative treatment as a whole are by no means satisfactory disappointing results are often due to factors which with better understanding of the case and with greater operative skill might be eliminated

The results in a few cases indicate that a badly torn ligament should be supported by a graft right from the beginning It would also seem that the remnants of the ligament should be damaged as little as possible so that their neurovascular elements can be preserved in the reconstructed ligament which without such elements may develop into a kind of neuropathic articular element The reconstructed or repaired ligament however does not need to be quite as good as a normal one if it is the only stabilizer damaged and if the muscles controlling the knee are uninjured

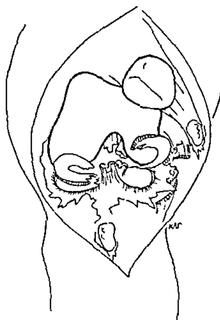


Figure 2. Schematic drawing of the injuries to two dislocated knees. In both cases the result of treatment was excellent.

and function of the knee joint is essential, although opinions still vary greatly with regard to fundamental questions (*Palmer* 1938, 1958, *Brantigan & Voshell* 1941, 1943, 1946, *Abbot, Saunders, Bost & Anderson* 1944, *O'Donoghue* 1950–1963, *DePalma* 1954, *Chapchal* 1954, *Kaplan* 1957, 1962, *Smillie* 1962, *Ficat* 1962, *Helfet* 1963, *Hallén & Lindahl* 1965, 1966). It is important that all components of the injury should be diagnosed preoperatively and not later than at operation. A clinical examination performed as early as possible after the accident is the easiest and most reliable method. For confirmation of the diagnosis various radiological methods have been suggested, such as roentgenographic examination under stress and arthrography, but these also involve certain risks.

In the recent literature operative treatment of total ligamentous injuries of the knee has been increasingly advocated (*Palmer, O'Donoghue, DePalma, d'Aubigné & Ramadier & Fayt* 1957, *Starr* 1962, *Ficat, Smillie, Helfet, Matzen* 1963). *Jonasch* (1961) among others recommends principally conservative treatment. *Lange* (1957) considers surgical intervention indicated if conservative treatment does not lead to a good result. Operative treatment is also indicated in the presence of associated injuries, *e.g.* of a meniscus, which can then be adequately

pratiquer dans les premiers jour qui suivent la lesion apres un minutieux examen et dans de bonnes conditions operatoires La continuite et la force des ligaments dechires doivent etre assures par l utilisation de greffes lorsque cela est necessaire meme dans le stade primaire Il est evident que tous les ligaments dechires doivent etre repares

ZU AMMENFASSUNG

Die Resultate operativer Behandlung von Seiten und Kreuzband schaden des Kniegelenkes werden durch eine Nachuntersuchung von 90 Patienten 1–8 Jahre nach der Verletzung besprochen Unter diesen waren 71 neue und 19 altere Bandschaden In 50 Fallen waren die Schaden multiligamentar In 13 Fallen fand sich nebenbei ein Kondylenbruch und in 47 Fallen eine Meniscusverletzung

Bei 52 Prozent der Falle von Neubeschadigten und bei 42 Prozent von Altbeschadigten waren die Resultate ausgezeichnet oder gut Die unbefriedigenden Resultate waren von Faktoren abhangig die durch bessere Diagnose und bessere Behandlung hatten vermieden werden konnen Operative Behandlung braucht nicht als Notfallsverfahren eingesetzt soll aber am liebsten wahrend der ersten Tagen nach dem Unfall gemacht werden nach sorgfaltiger Untersuchung und unter guten operativen Bedingungen Die Kontinuitat und Stärke des abgerissenen Ligamentes soll – wenn notig schon primar durch Transplantation sichergestellt werden Alle mit Sicherheit abgerissenen Bander sollen repariert werden

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Primary repair of ligaments gives better results than reconstruction. Probably it does not matter how or from what tendinous or fascial tissue the distally based graft is taken, since its circulation and innervation must necessarily be severed. In reconstruction the future aim should perhaps be to replace the ligament by a new ligament or tendon comprising neurovascular elements.

SUMMARY

The results of operative treatment of ruptures of the collateral and cruciate ligaments of the knee are discussed on the basis of a follow-up of 90 patients 1 to 8 years after the trauma. Of these, 71 were recent and 19 old ligamentous injuries. In 50/90 cases the injury was multiligamentous. Besides the ligamentous injury there was fracture of a condyle in 13 cases and lesion of the meniscus in 47 cases.

Excellent to good results were obtained in 52 per cent of the cases in recent injuries and in 42 per cent in old injuries. The unsatisfactory results were due to factors which might be reduced by improved diagnostics, treatment and after-treatment. Operative treatment need not be carried out as an emergency procedure but should preferably be performed within the first few days after the injury, after careful examination and under adequate operative conditions.

The continuity and strength of torn ligaments should be safeguarded by using grafts, when necessary, even at the primary stage. Evidently all torn ligaments should be repaired.

RÉSUMÉ

Les résultats du traitement opératoire des ruptures des ligaments latéraux et croisés de l'articulation du genou sont discutés sur la base du réexamen de 90 malades entre une et huit années après le trauma. Dans 71 cas il s'agissait de lésions ligamenteuses récentes, dans 19 cas de lésions anciennes. Dans 50 des 90 cas la lésion était multiligamenteuse. A côté de la lésion ligamenteuse il y avait fracture de condyle dans 13 cas et lésion du ménisque dans 47 cas.

Dans 52 pour cent des cas de lésions récentes et dans 42 pour cent des lésions anciennes, des résultats excellents ou bons ont été obtenus. Les résultats peu satisfaisants étaient dus à des facteurs qui peuvent être en partie éliminés par une amélioration du diagnostic, du traitement et du traitement complémentaire. Il n'est pas nécessaire de pratiquer d'urgence l'intervention chirurgicale, mais il vaut mieux la

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FAMILIAL INFANTILE OSTEOCHONDROSIS DEFORMANS TIBIAE. IDIOPATHIC TIBIA VARA

A Case Report

By

J A SEVASTIKOGLOU and I ERIKSSON

Received 6 VI 66

The angulation deformity of the tibia due to an idiopathic growth disturbance of the medial part of the proximal tibial epiphyseal cartilage and epiphysis is a well known pathological entity This condition described by *Erlacher* (1922) has been reported in isolated cases (*McCurdy* 1922 *Mau* 1924 *Nilsonne* 1929 *F Langenskiöld* 1929 *Blount* 1930 among many others) or large series (*A Langenskiöld* 1952 *Michail et al* 1959 *de Moraes & Perricone* 1959 *Golding & McNeil Smith* 1963) by several authors In 1937 *Blount* gave an extensive account of this localized growth disturbance and he distinguished an *infantile* and an *adolescent* type of the disease He further proposed the term osteochondrosis deformans tibiae and he presented the first description of the pathology of the disturbed function of the medial part of the epiphyseal cartilage *A Langenskiöld & Riska* published recently (1964) the most extensive series of osteochondrosis deformans tibiae by giving an account of 71 cases observed and treated by them This condition is by no means uncommon and except about 170 cases published prior to 1964 (*Langenskiöld & Riska* 1964) there are no doubt several other unpublished cases The etiology of the osteochondrosis deformans tibiae is largely unknown It was first believed that the condition represents an atypical form of rickets (*Hass* 1934) or epiphysitis of the Perthes type (*McCurdy* 1922 *F Langenskiöld* 1929 *Barber* 1942) but also infection (*Valentin* 1922 *Fulsdorf* 1931) dyschondroplasia (*Sloane et al* 1936) alteration of the lines of force on the medial portion of the upper tibial epiphyseal line (*Golding & McNeil Smith* 1936) and congenital disturbance of the ossification (*Rocher &

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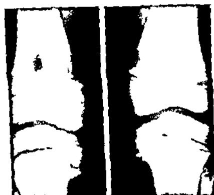


Figure 2. X-rays films of the knee region of case no. 2.

pronounced changes characteristic of bilateral idiopathic tibia vara and the patients were admitted to the Department for operative treatment. Arthrography of the right knee in both patients was performed before the operation and the arthrograms showed almost normal conditions in both cases (Figure 3). A correction osteotomy was performed on the right tibia and one month later the left tibia was operated on in the same way. A satisfactory correction of the deformities was obtained primarily with healing of the osteotomies after immobilization in plaster within approximately 3 months.

Case No. 3. A girl 12 years old, sister to the boys of case nos. 1 and 2. Tibia osteotomy was performed on the left leg elsewhere at the age of 4 years because of a pronounced varus deformity. Eight years later the deformity of the leg was still



a b

Figure 3. Left knee arthrography of the patients of case no. 1 (a) and no. 2 (b).



Figure 1. X-rays films of the knee region of case no. 1.

Roudil 1930) have been considered as etiological factors of this deformity. *Nilsonne* (1929) was the first to recognize the idiopathic character of this deformity. Genetical factors are known to be responsible for congenital or acquired skeletal deformities of different types and angulation at the level of a bony spur is frequently observed with hereditary deforming cartilaginous exostoses which may cause some confusion between that condition and the idiopathic tibia vara (*Blount* 1937). A racial tendency of the condition has also been maintained by *Bateson* (1966) based on the fact of the large series of *Langenskiöld & Riska* (1964) in a Finnish and that of *Golding & McNeil Smith* (1963) in a Jamaican population.

The authors have recently observed an idiopathic infantile osteochondrosis deformans of the tibia in 4 members of the same family which have been treated in our Department. A study of these cases from the genetic viewpoint was considered of interest and a short account of these cases is presented here.

THE CASES

Case Nos. 1 and 2. Two seven-year-old boys, identical twins, were submitted to the out-patient department for bow legs. The boys were born by normal delivery and were healthy earlier. Already at the age of 2 years they were examined by the pediatrician for bow legs but expectancy was suggested until the age of 6 or 7 years. Leg deformity increased however considerably during these years. An elder sister of the patients had been operated earlier in the Department for bow legs (case no. 3). The clinical and x-ray (Figures 1 and 2) examination showed pro-



Figure 2 X rays films of the knee region of case no 2

n unc d hanges characteristic (f bilateral idi pathic tibia vara and the patients w r admitte l t the Depa tm nt f r operative treatment Arthrography of the right kn e in I th patients wa perf rmed bef re the operation and the arthro-g m di cl ed almo t n rmal c nditi ns in b th cases (Figure 3) A c rrection te tomy was perf rme l on the right t bia and one month later the left tibia was p r t d n in the am way A satisfact ry correcti n f the def rmities was ob tain l primarily with healing cf th te tomie after imm il ilization in plaster within appr ximately 3 m nths

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Figu 3 Left kn arthrography of the patient of cas no 1 (a) and no 2 (b)

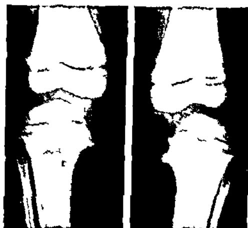


Figure 4 X rays films of the knee region of case no 3

pronounced and a varus deformity had developed on the right leg too The patient was therefore submitted to the Orthopaedic Department The x ray examination disclosed a bilateral idiopathic tibia vara (Figure 4) An osteotomy of the left tibia combined with a Phemister s epiphyseodesis of the lateral aspect of the proximal epiphyseal cartilage of the left tibia and fibula was performed Six months later a lateral epiphyseodesis of the tibia and fibula was performed on the right side A satisfactory clinical and X ray result was obtained 2 years later The patient is now 22 years old married and has two healthy children There is no deformity of the legs and the patient has no trouble from her knee at the present time

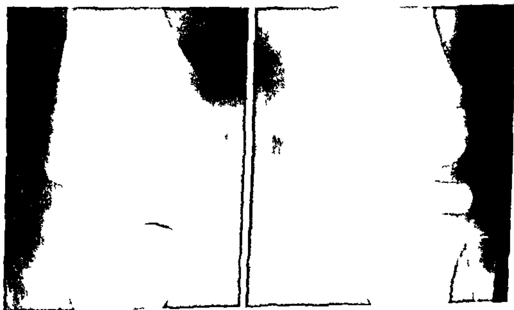


Figure 5 X rays films of the knee region of case no 4

Case No. 4. Concerned a 10 year old boy, brother of the earlier patients. No deformity of the tibiae was observed by the parents or during the routine medical examination at school. In connection with the radiological examination of the members of the family a slight idiopathic osteochondrosis of both the tibiae could be diagnosed (Figure 5). The clinical examination revealed a slight varus deformity of the tibiae needing no surgical treatment at the present time.

DISCUSSION

The reported cases provide good evidence for the occurrence of idiopathic tibia vara in these 4 members of the same family. The X-ray examination of the knees in the other members of the family, the pedigree of which is demonstrated in Figure 6, disclosed no deformities of the tibia in any of them. The familial occurrence of the deformity strongly suggests that it is under genetic control. The absence of manifestations in the parents makes a dominant transmission unlikely. The observed distribution of unaffected : affected in the sibship 2 : 4 (or rather 2 : 3 since the affected identical twins should be counted as a single genetic event) is compatible with a recessive inheritance. However, until further pedigree material has been collected no definite conclusions concerning the mode of inheritance can be drawn.

No case of idiopathic tibia vara with genetic transmission has been reported earlier. In the publication of 3 cases by *Evensen & Steffensen* (1957) two of the cases involved cousins, but no genetic analysis was performed by these authors. Medial tibial torsion of a hereditary type resulting in varus deformity of the legs has been reported by *Blumel et al.* (1957), but the reported cases had neither the clinical nor the X-ray characteristics of the idiopathic tibia vara. Familial osteochondritis dissecans of the knee with associated tibia vara has also been reported by *Tobin* (1957), but in this publication the clinical reports and the X-rays did not suggest the idiopathic tibia vara.

An interesting point in the present cases was the normal appearance of the knee and of the tibia epiphysis in arthrographies in the first two cases. *Evensen & Steffensen* concluded from arthrography studies of



Figure 6. Pedigree of the family. Affected individuals are indicated by black symbols.

their cases that a deformation of both the osseous and the cartilaginous elements of the medial part of the tibial epiphysis occurs in idiopathic tibia vara. This observation is in disagreement with the concept of *Blount* (1937) about the shape of the proximal end of the tibia in this condition. The arthrography findings in our cases (Figure 3) support the view of *Blount* and are in disagreement with *Evensen & Steffensen's* statement. An explanation for the divergence of findings in this respect might be sought in the development of the proximal part of the tibia in this condition with progressing age as it is demonstrated schematically by *Langenskiöld & Riska* (1964). It seems that a deformation of shape of the entire medial tibial condyle may occur in cases of infantile idiopathic tibia vara with prolonged development.

SUMMARY

Four cases of idiopathic osteochondrosis deformans of the tibia were observed in the same sibship. Two of the affected individuals were identical twins. These observations suggest that this localized growth disturbance is under genetic control. This localized skeletal growth disturbance occurred in this family probably as a result of the above though at present the mode of inheritance cannot be determined with certainty.

RÉSUMÉ

Quatre cas d'ostéochondrose idiopathique déformante du tibia ont été observés dans la même famille. Deux des sujets étaient des jumeaux vrais. Ces observations font supposer que ce trouble localisé de la croissance est sous contrôle génétique. Ce trouble squelettique localisé de la croissance est probablement héréditaire bien qu'il ne soit pas possible de déterminer avec certitude la forme de cette hérédité.

ZUSAMMENFASSUNG

Vier Fälle von ideopathischer Osteochondrosis deformans der Tibia wurden in derselben Verwandtschaft beobachtet. Zwei der ergriffenen Personen waren identische Zwillinge. Diese Beobachtungen legen es nahe, dass diese örtliche Wachtumsstörung unter genetischer Kontrolle vor sich geht. Diese lokalisierte Wachstumsstörung des Skelettes entstand in dieser Familie wahrscheinlich als ein Ergebnis dieser Kontrolle, obwohl zur Zeit die Art der Vererbung nicht mit Sicherheit festgestellt werden kann.

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From the Clinic for Orthopaedics and Traumatology (Head: Prof. K. J. Kallio, M.D.), University of Helsinki

CLOSED INTRAMEDULLARY NAILING OF TIBIAL SHAFT FRACTURES

A Comparison with Conservatively Treated Cases

By

P. Slätis and P. Rokkanen

Received 18.I.67

Intramedullary nailing in the treatment of fractures of the long bones was technically developed and popularized by Kuntscher in the 1940's (*Kuntscher* 1940). The method was widely adopted for a variety of orthopaedic conditions, but in the treatment of tibial shaft fractures the stability achieved with the original medullary nail was inadequate. Likewise, in open reductions the simultaneous severance of the medullary and periosteal nutrient systems frequently resulted in failure. The principles and results of the method were criticized by several authors (*Bauer* 1943, *Palmer* 1951, *Truela & Cavadias* 1956, *J. Bohler* 1957, *Lange* 1962) and regarded by many as unsuitable for the treatment of tibial shaft fractures.

Two recent technical improvements have revived interest in intramedullary nailing. *Firstly, the introduction of the clover-leaved nail* combined with the principle of reaming out the medullary cavity (*Kuntscher* 1958, 1959) in some cases made rigid fixation possible in the strict sense of the word. Secondly, the use of TV image intensifiers has made it possible to use a closed technique as a routine procedure. Closed intramedullary nailing with minor technical modifications has been practised by *Alms* (1962), *J. Bohler* (1963, 1965) and *Zucman & Maurer* (1965) with encouraging results. The value of the method is still debated, however, and comparative studies including selected series treated by other methods are lacking.

In this paper an attempt is made to assess the value of primary intramedullary nailing of tibial shaft fractures by comparing the early and



a *b*

Figure 1. A compound comminuted fracture of the tibial shaft associated with ... ntial displacement was sustained in a motor-cycle accident (a). Retention ... was ensured by conservative means and the fracture was treated with 10 mm ... intramedullary nail. Fixation was not stable. The patient walked with a stick within ... weeks and returned to heavy work in ... weeks ... (b) the fracture has united ... and the ranges of movement in the knee, ankle and tarsus joints were ...

... the results in nailed and conservatively treated fractures of comparable severity.

MATERIAL AND METHODS

During the years 1963–1964, 3? fractures of the tibial shaft in 31 patients were treated by closed intramedullary nailing at the Clinic for Orthopaedics and Trauma... In all cases the nailing was performed within 6 weeks after the trauma either as primary treatment or when retention of the fracture by a plaster cast proved difficult. Both closed and open fractures were operated upon. In cases with extensive soft tissue injuries operation was usually postponed until the soft tissue injury had healed.

Operative technique. The nailing was in all cases made by a closed technique ... of the fracture and subsequent introduction of the intramedullary nail

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Intramedullary nailing in the treatment of fractures of the long bones was technically developed and popularized by Küntscher in the 1940's (*Küntscher* 1940). The method was widely adopted for a variety of orthopaedic conditions, but in the treatment of tibial shaft fractures the stability achieved with the original medullary nail was inadequate. Likewise, in open reductions the simultaneous severance of the medullary and periosteal nutrient systems frequently resulted in failure. The principles and results of the method were criticized by several authors (*Bauer* 1943, *Palmer* 1951, *Trueta & Cavadias* 1956, *J. Böhler* 1957, *Lange* 1962) and regarded by many as unsuitable for the treatment of tibial shaft fractures.

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In this paper an attempt is made to assess the value of primary intramedullary nailing of tibial shaft fractures by comparing the early and



Figure 1. A compound comminuted fracture of the tibial shaft associated with [illegible] initial displacement was sustained in a motor cycle accident (a). Retention could not be secured by conservative measures and the fracture was treated with 10 mm Ø cloverleaf intramedullary nail. Fixation was then stable. The patient walked without a stick within 24 weeks and returned to heavy work in 47 weeks. At follow-up 2 years later (b) the fracture has united solidly and the ranges of movement in the knee, ankle and tarsus joints were good.

late results in nailed and conservatively treated fractures of comparable severity.

MATERIAL AND METHODS

During the years 1963–1964, 32 fractures of the tibial shaft in 31 patients were treated by closed intramedullary nailing at the Clinic for Orthopedics and Traumatology. In all cases the nailing was performed within 6 weeks after the trauma, either as primary treatment or when retention of the fracture by a plaster cast proved difficult. Both closed and open fractures were operated upon. In cases with extensive soft tissue injuries operation was usually postponed until the soft tissue injury had healed.

Operative technique. The nailing was in all cases made by a closed technique: Reduction of the fracture and subsequent introduction of the intramedullary nail

were controlled by the aid of a TV image intensifier mounted on a C arch allowing controls in two planes The medullary cavity was entered through the patellar tendon and reamed out with a flexible drill so that eventually a heavy clover leaved nail (mean diameter 11 mm) could be introduced into the medullary cavity (Figure 1)

In 17 cases fixation with the nail was rigid while in 15 cases additional plaster immobilisation was considered necessary This was usually applied one week after the operation and discarded 6–26 weeks later (mean 15 weeks)

The conservatively treated control group comprised 53 tibial shaft fractures in 52 patients treated during the same period in the clinic The controls were selected out of 112 fully documented fractures in adult patients in the following way

All the cases in the nailed and conservatively treated series were analysed regarding *mechanism of trauma* site of fracture severity of initial displacement severity of comminution and severity of wound From these data it emerged that the fractures in the conservative group represented less severe traumas than the nailed cases Thus *in order to render the two groups comparable* regarding severity of trauma 60 cases were discarded from the conservative group including most of the simple low energy fractures Among the 53 fractures remaining in the control group 10 later *needed bone grafting on account of delayed union*

The principles for conservative treatment were reduction and immobilisation in plaster Traction was not used and the patients were encouraged to move around on crutches *as soon as possible Delayed union was treated by early subcortical or* onlay grafting procedures with cancellous bone

The mechanism of the trauma in the two groups is shown in Table 1 Traffic accidents were the main causative factor *three fifths of the victims were pedestrians* The group of industrial accidents included fractures caused by compression or falls from a height Domestic accidents comprised fractures sustained by slipping stumbling and comparable low energy traumas

Table 1 Mechanism of trauma in the two groups of tibial shaft fractures under observation

Mechanism of trauma	Kuntscher nailed	Conservatively treated
Traffic accident	68 %	63 %
Industrial accidents (compression injuries falls)	10	10 %
Domestic accident (slipping stumbling and low energy traumas)	22 %	27 %

The site of the fracture There were no fractures in the upper third of the tibial shaft *In 69 per cent of the nailed and 68 per cent of the conservatively treated cases* the fracture was in the middle third in the remainder it was located between the middle and lower thirds Each group included two patients with double fracture

The severity of the fracture is analysed in Table 2 Initial displacement was based on the radiographs dropping of the distal part of the limb and obvious clinical

in tability Comminution was asses ed from the radiographs and the severity of the w und was graded according to the operative report

Age and sex Males outnumbered females in a ratio of 3 1 The age of the patients in the nailed group varied from 16 to 73 years (mean 38 years) and in the conservatively treated group from 16 to 71 years (mean 37 years)

Table 2 Severity of tibial shaft fractures in the two groups according to initial displacement degree of fracture comminution and type of wound

Type of tissue injury	Kuntscher nailed	Conservatively treated
Displacement		
Slight	56 %	60 %
Severe	44 %	40 %
Comminution		
None	50	53 %
Slight	37	36 %
Severe	13 %	11 %
Wound		
None	50	5?
Slight	28	28 %
Severe	22	17 %

All cases in the group under observation were followed until the end of the treatment In addition the patients were summoned to a follow up examination 2 years after the trauma The end results were obtained in 24 31 patients in the nail group (77 per cent) and in 42/52 patients in the conservatively treated group (80 per cent)

RESULTS

Rate of Union

In the nailed group union could not be evaluated by *clinical methods* since all fractures were rendered clinically stable 0–26 weeks after the operation by the metallic implant Neither could *radiographs during* the first months supply conclusive evidence of solid union which had to be assessed by disappearance of tenderness at the fracture site and improving walking ability In the conservatively treated group the mean time of union was 20 weeks based upon clinical *stability and full weight* bearing in a walking plaster In the 10 cases where delayed union necessitated subsequent bone grafting the *mean time of consolidation* was ?? weeks in 3 of these patients this time exceeded one year In the group of patients treated in plaster alone (42 cases) the *mean time of* union was 17 weeks and in none did it exceed 36 weeks

were controlled by the aid of a TV image intensifier mounted on a C arch allowing controls in two planes. The medullary cavity was entered through the patellar tendon and *reamed out* with a flexible drill so that eventually a heavy clover leaved nail (mean diameter 11 mm) could be introduced into the medullary cavity (Figure 1).

In 17 cases fixation with the nail was rigid, while in 1[illegible] cases additional plaster immobilisation was considered necessary. This was usually applied one week after the *operation* and discarded 6–26 weeks later (mean 15 weeks).

The conservatively treated control group comprised 53 tibial shaft fractures in 52 patients treated during the same period in the clinic. The controls were selected out of 112 fully documented fractures in adult patients in the following way.

All the cases in the nailed and conservatively treated series were analysed regarding *mechanism of trauma, site of fracture, severity of initial displacement,* severity of comminution and severity of wound. From these data it emerged that the fractures in the conservative group represented less severe traumas than the nailed cases. Thus, in order to render the two groups comparable regarding severity of trauma, 60 cases were discarded from the conservative group, including most of the simple low energy fractures. *Among the 53 fractures remaining in the control* group 10 later needed bone grafting on account of delayed union.

The principles for conservative treatment were reduction and immobilisation in plaster. Traction was not used, and the patients were encouraged to move around on crutches as soon as possible. Delayed union was treated by early subcortical or onlay grafting procedures with cancellous bone.

The mechanism of the trauma in the two groups is shown in Table 1. Traffic accidents were the main causative factor: three fifths of the victims were pedestrians. The *group of industrial accidents included fractures caused by compression or* falls from a height. Domestic accidents comprised fractures sustained by slipping, stumbling and comparable low energy traumas.

Table 1. Mechanism of trauma in the two groups of tibial shaft fractures under observation

Mechanism of trauma	Küntscher nailed	Conservatively treated
Traffic accidents	68 %	63
Industrial accidents (compression injuries, falls)	10 %	10
Domestic accident (slipping, stumbling and low energy traumas)	22 %	27

The site of the fracture. There were no fractures in the upper third of the tibial shaft. In 60 per cent of the nailed and 68 per cent of the conservatively treated cases the fracture was in the middle third; in the remainder it was located between the *middle and lower thirds.* Each group included two patients with double fractures.

The severity of the fracture is analysed in Table 2. Initial displacement was based on the radiographs, dropping of the distal part of the limb and obvious clinical

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Type f tissue injury	Kuntscher nailed	Conservatively treated
Displ ce ment		
Sl ght	56	60 c
Sev re	44	40 c'
C mm nuti n		
N ne	50 c	53 %
Slight	37 %	36 c
S vere	13 c'	11 c'
Wound		
N ne	50	55 c'
Slight	28	28 c
Severe	2? c'	17 c'

All a es in the gr up under ob ervation w re f llowed until the end of the tr atm nt In ad liti n the patients were summ ned to a f ll w up examination y a after the trauma The en l results were btained in 24 31 patients in the nail l gr up (77 per cent) and in 4? ?? patients in the conservatively treated group (80 per cent)

RESULTS

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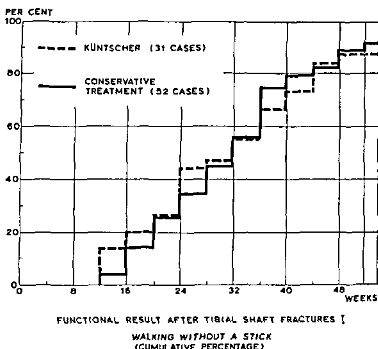


Figure 2. The early functional result in two series of tibial shaft fractures of comparable severity treated either by closed intramedullary nailing or by conservative methods. The conservatively treated group includes 10 cases in which bone grafting was done on account of delayed union during the first year of observation. The ability to walk without a stick during the first year after the trauma is in cumulative percentages.

Functional Results

In order to evaluate the early results of treatment the following criteria were chosen: 1) The time elapsing after the trauma until the patient was able to walk without a stick and 2) the interval between the trauma and return to work. The majority of patients were industrial workers for whom these data were accurately obtained. In sedentary workers and housewives, return to work was assessed by the time at which the patient could return to previous everyday activities.

The time elapsing before the patient could walk without a stick was about the same in the two groups (Figure 2). During the first six months after the trauma the nailed patients did better, but the difference was negligible at the end of the observation year.

The interval between trauma and return to work was likewise almost the same in the two groups (Figure 3). The trend here was also towards a better primary result in the nailed patients, but the results were soon comparable and by twelve months a relatively greater number, 90 per cent, of the conservatively treated patients had returned to work.

Residual Deformity

There was no significant difference between the two groups. Angulation exceeding 10 degrees was recorded in 1 case in the nailed group and in 2 cases in the conservatively treated group. Slight deformity in the 5–10 degrees range was more frequently seen after nailing than after conservative treatment.

Post-Traumatic Swelling

In both groups [illegible] patients complained of persistent swelling of the fractured limb. This became worse after strenuous exercise. In 1 case of the nailed and in 2 cases of the conservatively treated group this swelling was severe and partially disabling. In addition, 2 patients in the nailed group developed a pigmented varicose eczema around the lower leg without detectable varicosities in the unaffected leg. Two years after the trauma 1 patient of each group was using a walking stick.

Complications

In the nailed group 1 patient with a compound fracture developed a severe infection, eventually resulting in chronic osteitis. The nail was removed and the fracture treated later by bone grafting. The infection recurred and bony union has not yet been obtained.

Likewise, in the conservative group 1 patient with a compound fracture developed chronic osteitis. The infection gradually subsided and the fracture was successfully treated by bone grafting.

In the nailed group two refractures were recorded, one at 26 weeks and the other at 28 weeks. Both eventually healed, one was treated with plaster alone, the other by changing to a heavier nail.

DISCUSSION

A conservatively treated fracture of the tibial shaft heals basically by formation of a callus sheath around the fracture. The rate of miner

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The following criteria were applied as significant in assessing residual deformity:

Varus or valgus deformity Anterior or posterior curve	5 degrees or more
Rotational deformity	10 degrees or more

to resume work. The same was done at the follow-up examination 2 years after the trauma. The data obtained have been compiled in Table 3.

Table 3. Degree of joint movements in the knee, ankle and tarsus joints after tibial shaft fractures treated by closed intramedullary nailing and conservative methods

Joint movement	Küntscher nailed		Conservatively treated	
	At end of treatment	2 years after trauma	At end of treatment	2 years after trauma
Knee				
Good	58 %	87 %	77 %	90 %
Fair	42 %	13 %	21 %	10 %
Poor	–	–	2 %	–
Ankle				
Good	62 %	82 %	69 %	85 %
Fair	38 %	18 %	22 %	10 %
Poor	–	–	9 %	5 %
Tarsus				
Good	71 %	100 %	53 %	69 %
Fair	25 %	–	23 %	21 %
Poor	4 %	–	24 %	10 %

In the nailed group the range of movement in the knee joint was good in only 58 per cent of the cases at the end of the treatment. This was mostly due to tenderness in the knee region at the site of introduction of the nail. The distal joints had a better range of movement, which was considered good in 62 per cent in the ankle joint and in 71 per cent in the tarsus. Two years later the *mobility in the tested joints* had improved: movement was good in the knee in 87 per cent and in the ankle joint in 87 per cent of the cases. The range of movement in the tarsus was uniformly good and not restricted by more than 25 per cent in any of the cases.

In the conservatively treated group the knee joint had a good range of movement in 77 per cent at the end of the treatment, whereas the distal joints were more affected. Two years later the ranges of movement had improved: there was good movement in the knee joint in 90 per cent of the cases. These figures are similar to those obtained in the nailed group of fractures. In the tarsus, however, movement was good in only 69 per cent of the cases, which in this respect differed from the nailed group.

1963) However in selected cases with difficult fracture retention or combined with skin problems and quite often in multitraumatic patients presenting nursing problems the method of intramedullary nailing affords a valuable alternative to conservative treatment

SUMMARY

The results obtained in 32 fractures of the tibial shaft in 31 patients treated by closed intramedullary nailing in the years 1963–1964 are presented The medullary cavity was reamed out and the fracture stabilized with a heavy nail 11 mm in mean diameter All patients were operated upon within 6 weeks after the trauma

For comparison a series of 53 fractures of the tibial shaft in 52 patients was selected out of 112 fully documented cases treated by conservative methods during the same period

The two groups under observation were comparable regarding mechanism of trauma site of fracture and severity of displacement comminution and wound The series comprised more severe fractures than the average unselected series 50 per cent of the fractures were compound and the conservative control group included 10 fractures which needed bone grafting on account of delayed union

There were no significant differences between the two groups as regards the length of time elapsing before the patient could walk without a stick or the interval between trauma and return to work Two years later the residual joint stiffness in the knee and ankle joints were of the same degree whereas tarsus movement was better in the nailed group of patients

It is concluded that in most cases conservative treatment of tibial shaft fractures gives good results In selected cases where fracture retention is difficult in fractures combined with skin problems and in multitrauma cases presenting nursing problems closed intramedullary nailing may offer an alternative to conservative treatment

RÉSUMÉ

Les résultats du traitement de 32 fractures du corps du tibia chez 31 malades par clouage intramedullaire fermé dans les années 1963–64 ont présentés Le canal médullaire a été évidé et la fracture stabilisé par une forte tige d'un diamètre moyen de 11 mm Tous les malades ont été opérés dans l'espace de six semaines après le trauma

alisation depends on the ingrowth of extraperiosteal vessels into the callus and on the osteogenic properties of the callus tissue (*Slätis & Rokkanen* 1967). If, however, the fragments are tightly held together by means of metallic implants of sufficient strength, using either intramedullary nails (*Küntscher* 1958), heavy plates (*Hicks* 1959) or compression devices (*Müller, Allgöwer & Willenegger* 1965), the main route of fracture repair is converted to direct new bone formation between the apposed fragments (*Schenk & Willenegger* 1964). There are so far very few experimental data concerning the rate of union or tensile and compression strength of fractures treated by such implants. Although the methods of osteosynthesis have greatly improved during recent years, it is still justified to state that osteosynthesis of a fractured diaphyseal bone does not promote union, but at best yields reliable retention of the fragments and union within a normal time.

Rigid internal fixation makes the use of external splinting unnecessary and thus allows early mobilisation of the knee, ankle and tarsus joints. This is an important argument in favour of operative treatment. The results in this comparative study do not, however, reveal any significant difference between the nailed and conservatively treated fractures, although in the nailed group the good range of movement in the tarsus was impressive.

The functional result, as measured by the ability to walk without a stick and to return to work, were similar in both groups under observation. But this should be interpreted neither as evidence against the use of internal fixation nor as an argument in favour of intramedullary nailing. The fact that operative fixation in tibial shaft fractures yields results comparable to conservative treatment is worth noting. It should be emphasized, however, that the series comprises a higher proportion of severe fractures than are to be found in unselected series, and also that the best results with intramedullary nailing in this series were obtained in fractures of moderate severity.

The similarity of the results in the nailed and conservatively treated patients indicate that the severity of the trauma and the type of fractures basically determine the end result. The findings also support earlier observations that severe soft tissue injury is an essential causative factor in delayed union (*Ellis* 1958, *Wray* 1965) and residual joint stiffness (*Nicoll* 1964).

In our opinion, most fractures of the tibial shaft can be adequately treated by conservative measures, if necessary combined with early subcortical bone grafting according to Phemister-Charnley (*Charnley*

Im Hinblick auf dem Mechanismus des Traumas auf Bruchstelle und auf Schwere der Verschiebung Aufsplitterung und Hautwunde waren die beiden Gruppen vergleichbar In beiden Gruppen ergab sich eine grossere Anzahl von schwereren Bruchen als sich sonst in nicht ausgewahlten Serien durchschnittlich findet 50 Prozent der Bruche waren aufgesplittert und in der Gruppe der konservativ behandelten Fallen waren 10 die wegen verzogerter Heilung mit Knochenspange operiert werden mussten

Es war kein signifikanter Unterschied zwischen die beiden Gruppen im Hinblick auf die Zeitdauer bevor der Patient ohne Stock gehen konnte oder im Hinblick auf den Zeitraum zwischen Unfall und Ruck kehr zur Arbeitsfahigkeit Zwei Jahre spater war die Steifheit des Knies und des Fussgelenkes gleich gross wahrend die Beweglichkeit der tarsalen Gelenke in der genagelten Gruppe besser war

Die Schlussfolgerung ist dass konservative Behandlung in den meisten Fallen von Tibiaschaftbruchen erfolgreich ist In ausgewählten Fallen bei denen die Bruchstücke schwierig aneinander zu halten sind bei Bruchen mit Hautwundproblemen sowie bei Fallen die wegen viel facher Schaden Pflegeprobleme stellen kann die geschlossene Mark nagelung alternativ zur konservativen Behandlung verwendet werden

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A titre de comparaison, une série de 53 fractures du corps du tibia chez 52 malades a été sélectionnée parmi 112 cas de fractures parfaitement documentées, traitées par des méthodes conservatrices durant la même période.

Les deux groupes mis en observation étaient comparables en ce qui concerne le mécanisme du trauma, la localisation de la fracture, la gravité du déplacement, le caractère comminutif et la plaie. Les séries comportaient des fractures plus graves que la moyenne des séries non sélectionnées: 50 pour cent fractures étaient compliquées et dans le groupe de contrôle soumis au traitement conservateur il y avait 10 fractures qui ont nécessité une greff osseuse en raison d'un défaut de soudure.

Il n'a pas été constaté de différences sensibles entre les deux groupes par rapport à la durée des délais qui se sont écoulés jusqu'au moment où le malade a pu marcher sans canne ou en ce qui concerne l'intervalle entre le trauma et la reprise du travail. Deux ans plus tard, la raideur dans les articulations du genou et de la cheville était la même, alors que le movement du tarse était meilleur dans le groupe des malades traités par enclouage.

Il est conclu que, dans la plupart des cas, le traitement conservateur des fractures du corps du tibia donne de bons résultats. Dans les cas sélectionnés où la rétension de la fracture est difficile, dans ceux où la fracture est combinée à des problèmes de la peau ou dans les cas de trauma multipe présentant des problèmes quant aux soins à donner aux malades, l'enclouage intramédullaire fermé peut offrir une alternative au traitement conservateur.

ZUSAMMENFASSUNG

32 Brüche des Tibiaschaftes bei 31 Patienten, die durch geschlossene Marknagelung in den Jahren 1963–64 behandelt worden waren, werden besprochen. *Die Markhöhle wurde bei der Operation ausgeborht* und die Bruchestücke wurden duch einen groben Marknagel mit einem Durchmesser von 11 mm fixiert. Die Patienten wurden innerhalb von 6 Wochen nach dem Unfall operiert.

Unter 112 vollkommen dokumentierten Fällen von Brüchen des Tibiaschaftes, die durch konservative Methoden behandelt worden waren, wurde eine Gruppe von 53 Brüchen bei 52 Patienten zum Vergleich ausgewählt.

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From the Department f Orthopaedics (Head O Lindahl)
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THE RIGIDITY OF FRACTURE IMMOBILIZATION WITH PLATES

By

Olov Lindahl

Received 8 VI 66

In two earlier papers (6 7) the author has reported experimental tests of the rigidity obtained with various techniques of osteosynthesis for fracture of the femoral shafts these included the use of one or 2 Sherman plates In the present study a more thorough comparison is made of the rigidity of immobilization obtained with various plates that are commercially available The general principles for immobilization of fractures by this technique are also examined and discussed

MATERIAL AND METHODS

A n the earlier studies the tests were performed on femoral shafts from autops es in which a tran ver e fr cture had been produced by sawing This was then immobilized with the vari us types f plates and measurements of the rigid ty were ca ried out b the same meth d as bef re (6) except that the specimens were not subjected t axial ompre i n

Plat s tested

1	Sherman	7	Wenger (13 14)	13	A O†
2		8	"	14	A O†
3		9	Ordinary St ndard	15	Experimental
4	Eggers (3)	10	Ordinary Slotted	16	Lindahl‡
5		11	" "	17	Haggland
6	Ven ll (12)	12	A O†		

The appea an shap dimensi ns n l material are gi en in Figure 1 and Table 1

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* M nufa tu e l b AB Stille Wernar Stockh lm
‡ M nuf tu ed by bif St ckh lm
† Obtaine l fr m F rschungsin titut Dav A O-Instrumente Switzerland

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Table 1 Material and dimensions of the plates tested

No.	Name	Material	Length (mm)	Width (mm)	Thickness (mm)	Shape	Radius (mm)
1	Sherman	Vitallium	76.5	5.0	2.1	curved	17
2	„		114.2	6.1	2.9		26
3	„		136.2	6.8	2.9		26
4	Eggers		101.5	9.6	1.5–2.3	plane	–
			15[illegible].2	12.5	2.3–3.2		–
6	Venable		175.9	14.2	1.2–3.1	curved	14
7	Wenger modified		96.0	15.2	1.7–3.0		30
8	Wenger original		132.7	15.3	[illegible]2–4.3		19
9	Standard		10[illegible].4	10.8	2.2–2.8		37
10	Slotted		113.2	12.6	3.1–3.7		13
11			98.6	12.6	3.1–3.7		13
12	AO heavy	Stainless steel	102.3	16.0	4.7		25
13	AO weak		102.3	11.0	3.7		36
14	AO thin		103.0	11.8	0.8		4
15	Experimental		149.0	24.2	1.0		20
16	Linstahl	Kifilium	152.2	25.0	0.9–2.3		16
17	Haggland	Vitallium	203.0	14.9–35.5	2.8–3.6		40

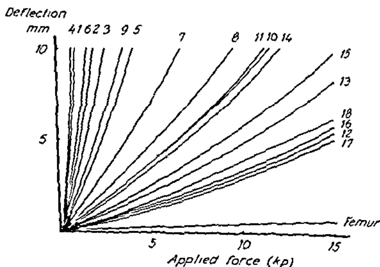


Figure [illegible] The relationship between the bending force applied 10 cm from the fracture and the deflection at the point of application of the force. For each plate the values used are those for the lowest strength. The figures relate to plates in Table 1. No. 18 relates to combination with two Sherman plates (no. 3) at right angles to each other. The lowermost curve relates to the deflection for an intact femoral shaft

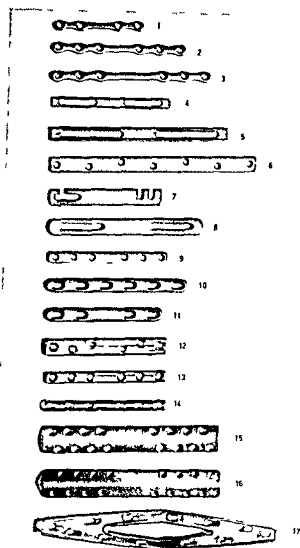


Figure 1 The fracture plates tested

RESULTS

As in the previous studies the rigidity of immobilization was tested by bending in 3 or 4 directions and by torsion The poorest rigidity was obtained for bending towards the plate so that the fracture space opened up It is not intended here to give a full account of all the values obtained for the relation between the applied force and the deflexion it sufficing for the present purpose to compare the various plates in respect of the lowest strength recorded (Figure 2) The rigidity of immobilization for the various plates varied widely and was of course lower for the thinner than the thicker ones

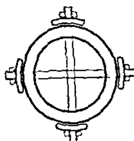


Figure 4 How to obtain complete immobilization with 4 plates

For immobilization of a fracture in the patient however account must be taken of other factors besides strength For instance it must be decided whether internal immobilization shall be used at all in view of the risk of infection the interference with the healing caused by the foreign material and surgical trauma and the scarring—even after an "atraumatic" operation The author tends to prefer the closed fracture treatment but there are situations in which an open reduction of the fracture and internal immobilization are to be preferred (10) and with improvement in the surgical technique in the widest sense such conditions may well become increasingly common

It is therefore necessary to weigh the pros and cons and it is assumed below that for some reason internal immobilization has been chosen As regards choice of material for the device it will suffice here to note that if the irritant effect is the same for stainless steel of the best quality as for Vitallium type alloys (Vitallium Kifilium Nobilium) then the former is to be preferred on mechanical grounds It usually has a greater elastic limit greater resistance to fatigue failure and greater toughness (elongation at rupture) and hence is capable of undergoing deformation without failure

Of particular significance in an assessment of various immobilizing devices is the greater interference with normal healing that may be caused by large than by small devices Three factors are probably involved in this respect (i) the difference in the amount of material and hence in the area of contact with the tissues (ii) the extent of surgical exposure and (iii) the prevention of normal vascularization and callus formation by the plate

In the case of immobilization with 2 plates facing each other and joined by bolts all 3 of these factors are involved and it is commonly considered that the sum of these disadvantages outweighs the initially

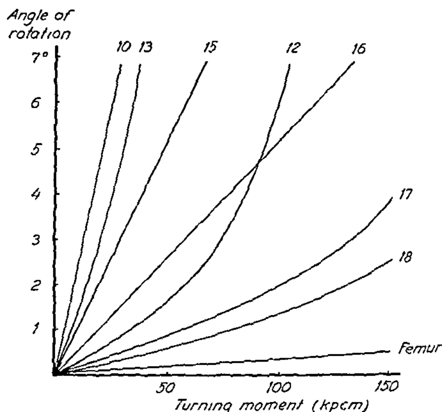


Figure 3. Relationship between torsional force and the corresponding angular rotation in the fracture. The figures relate to the same plates as in Figure 2.

A corresponding comparison of the rigidity as tested by applying torsion is presented in Figure 3. Since the torsional rigidity was extremely poor for the weaker plates, only the strongest have been included in the figure. While this property was largely parallel to the resistance to bending, there were certain differences and these will be discussed below.

DISCUSSION

From the mechanical aspect the best method of immobilization is that which gives the greatest rigidity of the fragments. There is no technical difficulty in designing devices that provide practically complete immobilization with the same rigidity as that of the femur itself, the strongest of the bones in the body. Such rigidity could be attained if the fragments were immobilized with, for instance, 4 plates placed perpendicular to one another in pairs and fixed together with bolts (Figure 4); even one such dual plate system would suffice, and plates of this type have been used (1, 9, 11).

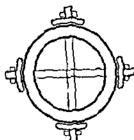


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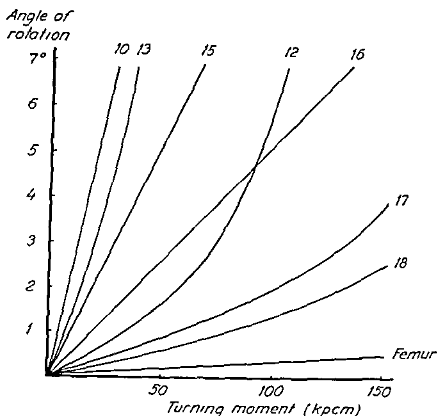


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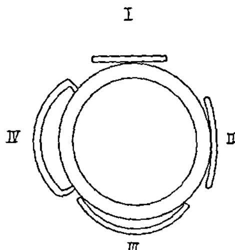


Figure 5 Various shapes of plates and the contact between them and the femoral shaft

plates In Figure 5 the application of 4 types to the femur is illustrated in cross section Plane plates of type I are fairly uncommon and afford poor torsional stability Whether a plate shall be classed as type II or III will depend on the curvature of the bone (the femoral shaft in the present context) as well as on the shape of the plate Except in the case of large shafts the Haggland and A O plates will fall in group II and they will then not be very effective in preventing rotation The Lindahl plate is of type IV and has two advantages First the edge of the plate makes contact with the shaft so that it will not rock second callus will probably form under the plate so that the biological disadvantage of the device will be overcome to some extent Despite its theoretically better shape from the mechanical aspect this plate is slightly less rigid than the A O and Haggland types and torsionally less stable than 2 Sherman plates This is because the material is extremely thin—0 9–2 3 against 4 7 mm for the A O plate It was designed thus to enable the plate to be deformed and adapted to femoral shafts of different diameters but it has since been found that such adaption can hardly be obtained even with material of this thickness and in future the plate will be made thicker the greater strength so obtained will provide greater rigidity than is possessed by the other plates discussed here

better immobilization Conclusive factual *support for this view is* lacking however and in the assessment account must be taken of a number of other circumstances not the least important being the surgeon s ability to perform an atraumatic operation and to avoid infection The failures subsequent to extensive operations are perhaps due less to the above factors than to *complications and then chiefly* infection (8)

As has been discussed elsewhere (6 7) the mechanical rigidity provided by other immobilizing devices than plates is generally poor with the exception of screws for oblique fractures In a discussion as to the best internal method it is therefore difficult to avoid the conclusion that for the moment some type of plate provides the best mechanical immobilization for a transverse fracture This has been shown clinically by Dencker (2) among others If dual plates are deemed unsuitable however it may be considered whether 2 plates at right angles provide a biologically acceptable solution or whether a single but stronger plate is to be preferred At present it is impossible to decide which is the technique of choice, neither of them have material disadvantages What is not acceptable however is for the plate to be so poorly designed that movement occurs that results in bone resorption and then prevents contact between the resorbed fragments This is presumably the explanation for the bad repute in which plate immobilization is held among many surgeons

It has been proposed that this disadvantage can be eliminated by using plates with slots instead of holes (Eggers Wenger) so that the resorbed fragments can move close together This however requires that the screws shall not be locked but then the immobilization will be further impaired and a vicious circle is entered where the whole apparatus serves *more as a coaptation than an immobilizing device* There are thus both theoretical and practical grounds for believing that this device does not function well in practice

Of the various plates intended primarily for the femur the Haggland A O and Lindahl plates are about on a par so far as resistance to *bending is concerned* Two quite weak Sherman plates set at 90 give almost as good immobilization (Figure 2) For torsional stability the relative rank of the 3 plates is the same but the difference between them is slightly accentuated Two Sherman plates are *slightly better in this* respect Under the circumstances it is difficult to decide which of these 4 methods is best from both the biological and mechanical aspects

A factor to be considered in this connection is the shape of the

a comparison was made for Sherman screws applied in each way In addition the effect of different drill diameters on the trength of anchorage was tested using the Sherman screws Finally the screws themselves were tested for their tensile strength

Pre-boring any threading and insertion of the screws were performed with the usual surgical instruments Since the tests were performed on specimens it was possible to handle the instruments with greater accuracy than would have been the case on the patient The strength tests were carried out at the National Testing Laboratory Stockholm with standard methods

RESULTS

The experimental screw proved to be on average the most securely fixed in the bone followed by the A O and last the ordinary Sherman screw (*Table 3*)

The anchorage was about twice as great for screwing in 2 cortical walls as one (Table 4) The resistance to withdrawal for screws in 2 walls of a tube is usually only slightly better than for *one wall owing* to the elasticity of the tube There was hus a favourable difference between the bone and for instance a steel tube in this respect

In a comparison of the strength of screws *after different types of*

Table 3 St ength f anchorage in the femoral c rtical bone 8 9 mm thick for var ous screws

Type f screw	No of te t	Tensile strength (kp) Mean	Range
Sherman	30	178	45–270
A O	20	232	78–315
Exp imental	20	240	75–315

kp (kg f) = kilopound = 9 80665 n tons = 2 2046 pound force

Table 4 Compar s n of anchorag strength on appl cation of Sherman screws thr ugh one r both cortical walls of femoral cortical sp cim ns (8 9 mm thick walls)

	No of test	Tensile strength (kp) Mean	Ran e
One c rti al w ll	10	181	45–250
T rti al walls	10	351	290–405

SCREW IMMOBILIZATION BETWEEN PLATE AND BONE

In the test performed in this investigation none of the screws fractured or worked loose in the bone. To fasten the weaker plates it was usually only the outer and inner holes on each side of the fracture that were used. The same applies to plate no. 12. For nos. 15 and 16 the 2 outer and inner holes on each side were used, and for no. 17 one outer hole and 2 inner holes on each side. The screws or the fixation between the screws and the bone was thus not the weakest point of the immobilization device in these single tests on dead bone.

For vital bone different conditions will obtain, and apart from the weakening of the bone through necrosis and demineralization there will also be repeated application of stress, which can lead to fatigue fracture of both screws and bone. In clinical practice the screws sometimes can break off and loosen.

To examine these factors a series of tests was made of the strength of the actual screws and of their anchorage in the bone under various conditions.

MATERIAL AND METHODS

To test the strength of the anchorage between the bone and the screws femoral shafts obtained at autopsies were used. The thickness of the compact bone was 8–9 mm in the tested areas. Three types of screws were inserted in one cortical wall, namely ordinary self threading Vitallium Sherman screws, A O screws of stainless steel intended for insertion after threading, and an experimental self-threading screw of stainless steel. The outside diameter, root diameter, pitch, pressure area per thread and shear area on an 8 mm length (the thickness of the cortical bone) are given in Table 2.

To find the differences in strength on screwing through one and 2 cortical walls

Table 2. Material and dimensions of the screws tested

	Material	Outside diameter (mm)	Root diameter (mm)	Pitch (mm/turn)	Pressure area per thread (mm²)	Shear area on 8 mm length (mm²)
Sherman	Vitallium	3.7	2.7	1.3	[illegible]	92.9
A O	Stainless steel	4.5	3.1	1.8	8.0	113.0
Experimental		4.8	4.0	0.8	5.0	120.0

The theoretical maximum shear area. It is usual to count with a loss of 15 per cent owing to the thickness of the screw at the periphery but this does not affect the comparison of the various screws.



Figure 6 Radiograph of an A O Plate (no 12) used to immobilize a femoral fracture the screws loosened owing to abnormal load

are therefore subjected to a bending force rather than pure traction The threads will then often act as notches and the strength in the case of these bending forces will be low In contrast to various stainless steels Vitallium has a low toughness which renders the material extremely susceptible to rupture on bending

The ordinary Sherman screws are probably too weak for their purpose In mechanical calculations of strength it is common to specify a safety factor of 3 it would then be necessary for the screw to tolerate a tensile strength about 3 times greater than the strength of its anchorage in the bone

The anchorage in the bone was strongest for the experimental screw which as is seen from Table 2 also has the greatest shear area in the bone by virtue of its greater outer diameter It is however not so much stronger than the A O screw as would be expected from its shear area probably because it is self threading while the hole for the A O screw is made with a tap This cuts much more exact threads than can be obtained with a self threading screw which to some extent crushes the bone and thus presumably reduces the strength of the anchorage With an ideal plate screw design the anchorage in the bone is certainly the weakest point Even though in a single experiment it is possible to obtain an extremely strong anchorage between plate and bone by using many screws with a large shear area in the long run it will probably be the weakening of the bone in the threads that will decide where the immobilizing device will most likely fail Figure 6 shows a fracture of the femur in which the fragments were immobilized with an A O plate

pre boring it was found that a narrower centre drill than that recommended by the manufacturer gave a slightly greater strength (Table 5)

In a comparison of the actual screws with respect to their own strength the larger steel ones were much stronger than the narrower Vitallium ones (Table 6) The mean strength of the Vitallium screws was greater than that of the anchorage between the screw and the bone (8 mm cortical bone 2 walls) but there were a few screws that were weaker than the anchorage so that the screws might sometimes break simply because they are weaker than the bone in which they are placed

Table 5 Comparison of anchorage strength for Sherman screws in femoral cortical bone (8–9 mm thick) where the pre boring was done with 2 8 and 3 0 mm centre drills

Centre drills (mm)	No of tests	Tensile strength (kp)	
		Mean	Range
3 0 mm	10	181	45 250
2 8 mm	10	201	70 290

Table 6 Comparison of tensile strengths of various screws

Type of screw	No of tests	Tensile strength (kp)		Lowest ultimate strength (kp/mm)
		Mean	Range	
Sherman	20	409	255 475	45
AO	10	511	415–620	55
Experimental	10	710	635 815	51

DISCUSSION

As in the discussion on the rigidity of the plates it is necessary here too to distinguish between the purely mechanical conditions in a single experiment and the results for vital bone which undergoes gradual change in calcification during healing

The screws should be considerably stronger than their anchorage in the bone but this does not apply to the ordinary Sherman screws Even if the plates are fixed with several screws the full tractive force will occasionally be borne by only one of them and they will then rupture in turn Screws may also break because they are inserted askew and

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SUMMARY

Seventeen different types of fracture plates have been tested for rigidity against bending and torsion when affixed to femoral shafts obtained at autopsy in which transverse fractures had been sawn

The best fixation was obtained with the heavier plates (A O Hagg land Lindahl) An examination of the strength of the anchorage between the various screws and the bone and of the strength of the screws themselves was also performed The usual Vitallium screws were found to be weak and to provide a poor anchorage in the bone while the A O screws were satisfactory in this respect The principles associated with the immobilization of fractures with plates are discussed as is the design of the plates and screws in respect of the best possible mechanical and "biologic conditions for healing of the fracture

RESUME

Dix sept différents types de plaques de fractures fixées à des corps femoraux obtenus par autopsie dans lesquels des fracture transversales avaient été provoquées ont été soumis à des épreuves de rigidité contre la flexion et la torsion

La meilleure fixation a été obtenu avec les plaques lourdes (A O Hagglund Lindahl) Un examen de la force de l'ancrage entre les differentes vis et l os et de la force des vis elles memes a également été pratiqué On a trouvé que les vis courantes de Vitallium sont trop faibles et assurent un mauvais ancrage dans l os alors que la vis A O donne satisfaction a cet égard Il est discute des principes liés à l immobilisation des fractures vissées au moyen de plaques et de la forme des plaques et des vis en vue de fournir les meilleures conditions mecaniques et biologiques possibles pour la guerison de la fracture

ZUSAMMENFASSUNG

Siebzehn verschiedene Typen von Bruchplatten wurden auf Widerstandskraft gegen Beugung und Drehung geprüft nachdem sie an bei der Autopsie erhaltenen Femurschaften in die eine Querfraktur gesagt worden war fixiert worden waren

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with 6 screws. The anchorage was extremely good when tested at operation, but when the patient was in error allowed to walk and work with the full weight on the leg 4 weeks after the operation, the screws loosened in the bone, but they were not fractured nor was the plate bent. What are then the factors that are responsible for the weakening of the anchorage in the bone with time? It is conceivable that by virtue of its irritant effect on the tissue the actual material in the screw can cause resorption of the bone or demineralization in the threads. It is also known that during healing there is a general demineralization throughout the region of fracture, including the site for the screw holes. Moreover, under moderate pressure there is a tendency for calcification to occur, while at higher pressures there is resorption of the bone (4). For these reasons it is best to use materials that exert the smallest irritant effect, to use many screws so as to distribute the pressure, to insert them accurately so that they all bear their share of the traction, to thread the holes and to ensure that there is a fairly large shear area between the screws and the bone. What shape of screw is best can be decided only on the basis of practical tests. The screws now in common use (Sherman) probably do not satisfy these theoretical requirements, but the relatively new A. O. screws are satisfactory in this respect. Another factor that may be of importance so far as bone resorption in the threads is concerned is the temperature generated in the bone during drilling. As the drills are usually run at a high speed and the actual drill is not very sharp, a high temperature will result. It might be expected that a high temperature would be an advantage, since the bone is then devitalized and hence will not decalcify over a long period, but the opposite, a more rapid decalcification, might occur.

To summarize, the anchorage of a plate should satisfy the following requirements: the rigidity and shape of the plate should be such that the strength of immobilization is roughly equal to that of the bone, enough screws must be used (for instance 4 on each side of the fracture) and the shear area should be large, the material should be as little irritant as possible.

These requirements are at present best fulfilled by the A. O. plate; when it has been modified the Lindahl plate will also meet these demands.

The above comments relating to tests on femoral shafts are probably applicable also to other long bones, though possibly not to the tibia. Owing to its triangular cross section and proximity to the skin, immo-

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halten (A O Haggland Lindahl) Eine Untersuchung der Veranker ungsstarke zwischen den verschiedenen Schrauben und dem Knochen und der Starke der Schrauben selbst wurde ebenfalls ausgefuhrt Die gewohnlichen Vitalliumschrauben erwiesen sich als schwach und ergaben nur eine schlechte Verankerung im Knochen wahrend die A O Schrauben in dieser Hinsicht zufriedenstellend waren Die Prinzipien in Verbindung mit der Ruhigstellung von Bruchen werden besprochen ebenso die Konstruktion von Platten und Schrauben hinsichtlich der best moglichen mechanischen und biologischen Bedingungen zur Bruchheilung

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FRACTURE HEALING AND MAST CELLS

I. *The Periosteal Callus in Rats*

By

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The rate of fracture healing under normal and pathological conditions and the mineral metabolism, biophysical properties and reaction of bone to trauma have recently been given considerable attention (*Nilsonne* 1959, *Koskinen* 1959, *Falkenberg* 1961, *Wendeberg* 1961, *Hulth & Olerud* 1964). The elements of callus—blood cells, blood vessels, fibrous tissue, cartilage and bone—are well known (*Collins, Ham & Leeson, Ham & Harris, McLean & Urist*). And yet there is still controversy as to which of these elements plays the principal role in bone regeneration, and biochemical knowledge of the calcifying mechanism is incomplete.

A striking parallelism between certain features of the specialized histiocytes known as mast cells (*Ehrlich*) and the formation of callus in bone repair may be observed in regard to metachromatic stainability with thiazine dyes and reaction to hormonal stimuli.

In their metabolism mast cells are biochemically closely related to histamine (*Riley & West* 1953), hyaluronic acid (*Asboe-Hansen* 1950), 5-hydroxytryptamine (*Parrat & West* 1956) and heparin-like mucopolysaccharides (*Jorpes, Holmgren & Wilander* 1937). The granules of the mast cell stain heavily metachromatically. One of the most impressive characteristics of the colloid ground substance in callus tissue, too, is its metachromasia, indicating high molecular polysaccharides (*Lenander* 1964). A close association between mucopolysaccharides and the phase of calcification has been observed. The mast cells diminish and develop vacuoles during treatment with cortisone and the spread of metachromatic substance decreases (*Asboe-Hansen* 1950, *Cavallero & Braccini* 1951, *Stuart* 1951, *Fulton & Maynard* 1953). If fractures in rats heal under the influence of cortisone new bone for

mation is greatly delayed or totally arrested (*Koskinen* 1959). Thyrotropin + somatotropin increase the number of mast cells (*Wegelius & Asboe-Hansen* 1956) and the metachromatic staining of the ground substance in connective tissue. The action of thyrotropin + somatotropin vigorously promotes the formation and maturation of the cells in the repair of experimental fractures in rats (*Koskinen* 1959).

The granules of the mast cell contain alkaline phosphatase (*Noback & Montagna* 1946, *Wislocki & Dempsey* 1946, *Riley & Drennan* 1949) and in addition acid phosphatase (*Montagna & Noback* 1947, 1948). Alkaline phosphatase has been traced to the region of the hypertrophied cartilage cells in the growing zone of the epiphyseal plate in the rat tibia (*Morse & Greep* 1951).

The mast cell has attracted little attention as an element in osteogenesis. During the process of wound healing of the skin in rats the number of mast cells increase in the vicinity of the growing tissue (*Wichmann* 1955).

S^{35} studies, however, have revealed the presence of mast cells both inside and outside the bone substance in the growing proximal end of the tibia in rats (*Duthie & Barker* 1955). Deposition of S^{35} in a healing fracture site could not be established.

The purpose of this experimental study of fracture repair has been to discover the location and behaviour of the mast cells in the periosteal callus during the process of endochondral ossification.

MATERIAL AND METHOD

The material consisted of 25 adult white rats of both sexes, weighing on an average 134.6 g (range 120–145 g) at the start of the experiments. The animals had been reared under the same physical conditions and fed usual laboratory diet and tap water.

Under ether anaesthesia the right tibia and fibula were manually fractured. Specimens for histological examination were taken from the periosteal callus of the tibial fracture and control specimens from the periosteum and muscles of the left tibia. Before dissection roentgenograms were taken of both lower extremities.

Histological specimens were taken on the days 1, 2, 3, 4, 5, 6, 7, 9, 11, 13, 15, 19, 21 after fracturing. The preparations were fixed in a 4 per cent aqueous solution of basic lead acetate for 48 hours, prepared and cut into 10 μ sections in the manner previously used by one of the authors (*S. Lindholm* 1959). Sections were stained in a 1 per cent toluidine blue aqueous solution for 1–2 minutes. The mast cells in the periosteal callus were studied in a *Leitz binocular microscope*.

The mast cells were counted in 2 sq.mm (= 30.2 high power (×450) fields). The results were recorded on the average per sq.mm. The number of cells per cu.mm



F gure 1a and 1b Agg egation of strongly metach matically sta ning mast cells in y ung und ff rentiat l mesenchymal callus Cells apparently in a state of ex haust degranulation Metach omati g anules (C) in th su roun ling matrix S me lls (D) have almost disappeared Mi photos a) × 100 and b) × 400 F ur-day old xp rimental fracture in a rat

F gu a and 2b Mast cells n the vicinity of the metach omatic one (MZ) of p e h n lr blasts Mature rt lage (C) in left low r corner Microph tos a) × 100 and b) × 400 S x-day ll xper mental fra ture in a rat

m s l d term n d from Floleru (1944) formula $n = \frac{1000}{a+d-2h}$ where n is the number f nu lei p er sq mm a the thickness of the section (10 µ) d the diameter of th nucl u in s (5) and h the di meter f the smallest nu lear segment found in the ti ue (0 5µ)

Unequal and va iable localization f the ma t cell in the proliferat ng c n



Figure 3. X-rays of fracture from Figure 2. Earliest visible signs of mineralization in the callus cuff.

nective tissue in the vicinity of the newly formed cartilage made any quantitative study uncertain. Therefore we decided to make only an approximate count of the mast cells in the early (after 24 hours), middle (on the 7th and 13th days) and late phase (on the 19th day) of repair.

RESULTS

We were impressed by the progressive increase in the number of mast cells from the 3rd to the 13th day. Thereafter the number of cells continually decreased and on the 19th day the situation was quite the same as on the 1st day after the trauma. In the control material we found a large number of mast cells in the periosteum, subcutis and muscle, but there were no variations in the number of cells during the experiment. In the callus the mast cell usually had a deeply staining nucleus and contained plenty of metachromatic granules. In the controls the nucleus appeared somewhat smaller and contained fewer metachromatic granules. Initially the increase of metachromasia in the ground substance ran parallel to that of the mast cells, but there was a diminution after the 7th–9th day. Formation of cartilage began on the 2nd–3rd day. The cartilage showed significant metachromatic properties. Macroscopic and palpable callus was demonstrated on the 4th day. The fracture was stable by the 19th day; firm union of the fragments was established clinically and roentgenologically. Macroradiographically (Figure 3) the first signs of mineralization could be visualized on the 5th day, and by the 15th day union in the middle part of the ossifying collars was almost complete.

Multiplication of mast cells was mainly observed in the location where the mesenchymal blastema was undergoing differentiation (Figure 1). The majority of cells were situated in the vicinity of the carti-

lage zone (Figure 2) but not in the cartilage itself being more scattered at the periphery of the periosteal cuff No cell divisions were seen in the callus Perivascular aggregation was not an outstanding feature

After 24 hours no cartilage could be seen as yet but there were already areas of slightly metachromatic proliferating connective blastema The mast cell counts were as follows 1st day 20 per sq mm = 1428 per cu mm 7th day 41 per sq mm = 2927 per cu mm 13th day 58 per sq mm = 4141 per cu mm and 19th day 18 per sq mm = 1285 per cu mm fibrous callus tissue

DISCUSSION

The mast cells proliferate in the callus tissue from the 3rd to the 13th day probably by invasion they were not seen to divide within the callus The function of the mast cells in the callus probably consists in synthesis and secretion of high molecular substances necessary for the metaplasia of the connective tissue in the process of endochondral ossification

Closer contact with the growth zone of cartilage and bone formation runs parallel with exhaustive degranulation and transformation or disappearance of the mast cells Their role as furnishers of alkaline phosphatase phosphorylase and other enzymes must be taken into account besides their ability to produce histamine 5 hydroxytryptamine and heparin

Delay of callus formation by ACTH and acceleration of fracture *healing by STH* are possibly secondary results of the suppression and activation of the mast cells in the periosteal callus a point which requires further investigation

It appears likely that the mast cells do not initiate the process of ossification but promote it The inducing mechanism may be *part* of the regenerative power possessed by specific cells in this case the osteoblasts in the periosteum and endosteum

SUMMARY

Typical mast cells aggregate in the mesenchymal part of the periosteal callus of experimental fractures *in rats* An increase in number probably by invasion was observed from the 3rd to the 13th day of repair Cells in the periosteum subcutis and muscle of the unfractured

leg were screened as a control. The number of mast cells in these did not show any variations during healing.

Mast cells in close contact with the metachromatically staining zone in the periosteal callus cuff are seen to degranulate and disappear from the visual field. No mast cells were seen within the areas of newly formed cartilage or bony trabeculae.

The mast cells are obviously intimately involved in the process of bone repair in rats, mainly in the region where preformation of cartilage takes place. It seems likely that the mast cells furnish substances essential for the process of endochondral ossification.

RÉSUMÉ

Des mastocytes typiques s'accumulent dans la partie mésenchymale du cal périostal des fractures expérimentales chez les rats. Une augmentation de leur nombre, qui se produit probablement par invasion, a été observée entre les 3ème et 13ème jours de la régénération. Les cellules du périoste, du tissu sous-cutané et du muscle de la jambe non fracturée ont été examinées à titre de contrôle. Il n'y avait là aucune variation du nombre des mastocytes pendant le processus de guérison. On a observé que les mastocytes en contact étroit avec la zone colorée des corpuscules métachromatiques du périoste du cal pouvaient perdre leurs granulations et disparaître du champ visuel. Aucun mastocyte n'a été observé là où il y avait formation récente de cartilage ou des trabécules mâles.

Les mastocytes sont intimement liés au processus de régénération des os chez les rats, principalement dans la région où il y a préformation de cartilage. Il semble que les mastocytes fournissent les substances essentielles nécessaires à l'ossification endochondrale.

ZUSAMMENFASSUNG

Im Mesenchymalen Teil des periostalen Callus bei experimentellen Knochenbrüchen bei Ratten ergibt sich eine Anhäufung typischer Mastzellen. Eine Zunahme der Anzahl, die wahrscheinlich durch Invasion zustande kommt, wurde vom 3.–13. Tage der Heilung beobachtet. Zellen von Periost, Subcutis und der Muskulatur des nicht gebrochenen Beines wurden als Kontrolle benutzt. Die Anzahl der Mastzellen zeigte dort während der Heilung keine Variationen.

Eine Degranulierung und ein Verschwinden aus dem Blickfeld wurde

an denjenigen Mastzellen gesehen die mit der metachromatischen Farbzone in nahem Kontakt waren Im Gebiete neugebildeten Knorpels und der Knochentrabekel waren keine Mastzellen zu sehen

Bei Ratten sind Mastzellen offenbar mit dem Prozess der Knochenheilung verbunden besonders in Regionen in denen Praeformation von Knorpelgewebe stattfindet Wahrscheinlich liefern die Mastzellen Substanzen die fur die enchondrale Ossifikation wichtig sind ab

ACKNOWLEDGMENT

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Acta orthop Scandinav 38 123 128 1967

From the Department of Surgery Vaasa Central Hospital Vaasa Finland

FRACTURE HEALING AND MAST CELLS

II Influence of 17 hydroxy corticosterone

By

S LINDHOLM R LINDHOLM & P LIUKKO

Received 29 xi 66

The precence and increment in number of mast cells in the periosteal callus cuff of experimental fractures have recently been clearly de monstrated (*Lindholm Lindholm & Liukko* 1966) in rats fed the ordi nary laboratory diet Mast cells are known to diminish in size and develop vacoules during theatment with cortisone (*Asboe Hansen* 1950 *Cavallero & Braccini* 1951 *Fulton & Maynard* 1953 *Wegelius & Asboe Hansen* 1956) New bone formation is delayed under the influence of cortisone (*Koskinen* 1959 *Hulth & Olerud* 1964)

In order to elucidate the relationship between mast cells and the process of fracture healing the influence of 17 hydroxy corticosterone on the mast cells in the periosteal callus was investigated

MATERIAL AND METHOD

The material con isted of 98 white rats of both sexes weighing on an average 101 g at the start of the experiments The animals had been reared under the same ph ical c nditions and fed the usual laboratory diet and tap water

Under ether anae the ia the right tibia and fibula were manually fractured (Figure 3) 2 mg 17 hydroxycorticosterone (hydrocortisone)[1] was administered ub utane u ly every day to all the rats The animals were sacrificed and histo log cal pecimen were taken on the days 1 2 3 4 5 6 8 10 12 14 16 18 29 3 aft r fracturing The specimens consisted f callus tissue from the external it and ntrol sp cimens were removed f om the periosteum of the left tibia the heart the lung and the t mach Roentgenograms were taken of b th lower extre mitie The prepar ti n were fixed in a 4 per cent aqueous s lution of basic lead acetate and tained in a 1 per cent t luidine blue aque us solution as described l ewh e (S Lindh lm 1959) The mast cells were studied in a Leitz binocular

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RESULTS

For technical reasons it was not possible to make any quantitative mast cell count The impression of a progressive increase in the number of mast cells from the 8th day after trauma was obtained Between the 10th and 16th days the mast cell count appeared to be high and then decreased until the 32nd day when no more mast cells could be seen During the first week of fracture healing only a few and scattered mast cells were seen in the metachromatic ground substance of the early callus tissue The metachromasia in the ground substance reached its maximum between the 5th and the 6th day and decreased continually after the 10th day The formation of cartilage took place from the 3-4th day and bone could be visualized histologically and roentgenologically on the 8th day (Figure 3) The fracture was stable when manipulated on the 22nd day and the callus appeared to be calcified roentgenologically (Figure 4)

The controls showed numerous large mast cells in the periosteum muscle and subcutis an abundance of mast cells of smaller size in the stomach only a few cells in the heart and none in the lung

The mast cells seen in the callus were both large and small the granules stain isometachromatically violet or reddish and varied concerning homogeneity and size Some cells do not differ very much from surrounding fibrocytes in shape size and nucleus (Figure 1) others appear like mature deeply staining and densely packed large granulated mast cells whose nucleus is entirely blurred by intracellular granules (Figure 2)

The following mast cells counts were obtained 3rd day 10 per mm = 714 per cu mm 10th day 74 per mm = 5284 per cu mm 14th day 93 per mm = 6447 per cu mm and 22nd day 9 per mm = 643 per cu mm

DISCUSSION

The previously known effects of cortisone on the morphology of the mast cells could be observed in the callus during the early phases of repair Our observations support the theory that mast cells are formed *in situ* from fibrocytes (Figure 1) Cortisone causes moderate to extreme retardation of bony union (*Hulth & Olerud* 1964 *Koskinen* 1959) A moderate delay was observed by us One explanation may be a difference between cortisone and hydrocortisone in their action on bone formation It may perhaps be concluded that the process of

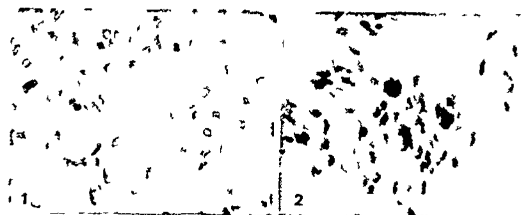


Figure 1 Aggregation of mast cells of medium and small size some ressembling fibrocytes with a weakly metachromatic and homogenously staining plasma Nuclei clearly visible Ground substance almost unstained Microphoto ×1000 (oil immersion) Six-day-old experimental fracture in a rat under the influence of hydrocortisone

Figure 2 Large heavily staining granulated mast cells near the cartilage zone in the periosteal callus The cells appear to be in a stage of maturation and degranulation Ground substance invaded by granules Microphoto ×1000 (oil immersion) Six-day-old experimental fracture in a rat under the influence of hydrocortisone

microscope during the process of healing until the 32nd day An approximate cell count was done and the number of cells per cu mm was calculated according to a technique described elsewhere (Lindholm Lindholm & Liukko) The cell count was performed in the early (on the 3rd day) middle (on the 10th and 14th day) and late phase (on the 22nd day) of repair



Figure 3 Experimental eight day old fracture of the right hind leg in a rat under the influence of hydrocortisone Clearly visible callus

Figure 4 Experimental twenty-two-day-old fracture of the right hind leg in a rat under the influence of hydrocortisone Callus cuff completely mineralized and fracture clinically stable

RESULTS

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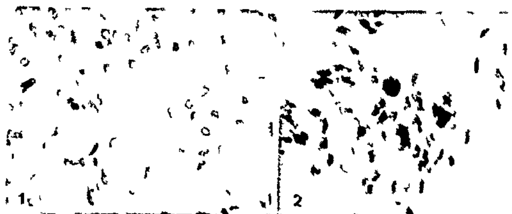


Figure 1. *Aggregation of mast cells of medium and small size, some ressembling fibrocytes with a weakly metachromatic and homogenously staining plasma. Nuclei clearly visible. Ground substance almost unstained. Microphoto ×1000 (oil immersion). Six-day-old experimental fracture in a rat under the influence of hydrocortisone.*

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microscope during the process of healing until the 32nd day. An approximate cell count was done and the number of cells per cu mm was calculated according to a technique described elsewhere (Lindholm, Lindholm & Liukko). The cell count was performed in the early (on the 3rd day), middle (on the 10th and 14th day) and late phase (on the 22nd day) of repair.

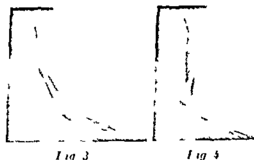


Figure 3. *Experimental eight-day-old fracture of the right hind leg in a rat under the influence of hydrocortisone. Clearly visible callus.*

Figure 4. *Experimental twenty-two-day-old fracture of the right hind leg in a rat under the influence of hydrocortisone. Callus cuff completely mineralized and fracture clinically stable.*

mation de cartilage et d os a ete legèrement retardee par rapport aux animaux de séries anterieures qui n ont pas ete traites aux steroides Malgre le retard dans la formation du cal la fracture a fini par se souder parfaitement

Les mastocytes ont de plus grandes differences quant a la grandeur aux proprietes metachromatiques et a la granulation que dans le groupe précédent d animaux non traites Les mastocytes se creent probablement par une transformation metachromatique des fibrocytes

ZUSAMMENFASSUNG

Nach Zerbrechen der rechten Tibia und Fibula wurden 28 Ratten tagliche subcutane Injektionen von 2 mg 17 Hydroxycorticosterone (Hydrocortisone) gegeben Histologische Proben wurden mit Toluidine blau gefarbt und die Mastzellen wurden beobachtet Eine Zunahme der Zahl der Mastzellen wurde vom achten Tage an mit einem Maximum zwischen den 10 und 16 Tage beobachtet

Im Vergleich mit Tieren in fruheren Versuchsserien die nicht steroidbehandelt worden waren war die Formation von Knorpel und Knochengewebe massig verzogert Trotz der verzogerten Callusbildung heilten die Knochenbruche schliesslich gut

Die Mastzellen zeigten grossere Differenzen in Umfang metachromatischen Eigenschaften und Granulation als die der fruheren Gruppe von nicht behandelten Tieren Die Mastzellen werden wahrscheinlich durch metachromatische Transformation der Fibrocyten gebildet

ACKNOWLEDGEMENT

We are ind l ted to the Dep rtment of Lathology (Hea l *P Fortel us* M D) the Department f R diology (Hea l *F Aut o* M D) and the Board of Direct rs Vaasa Cent l Ho pital Vaasa Finland for spons ring this research

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4 Halth A & Ol ru L S (1961) Early fractur c llu in n rmal an l c rtisone tr t l rat A ta orth p scand 31 1 ?3

mineralization is influenced by the presence of mast cells The formation of cartilage from chondroblasts need not necessarily depend on the function of the mast cells The delay in healing seems to concern the process of maturation and mineralization of the cartilage rather than the early phases of chondrogenesis

It is difficult to explain why the morphology of the mast cells shows variations under the influence of cortisone Retardation of maturation and prolongation of heteroplasia may be valuable hypotheses for further investigations In any case our mast cell counts suggest an initial depression followed by a compensatory increase of cells to a somewhat higher level than in the normal series (*Lindholm, Lindholm & Liukko*) However the method of counting mast cells must be improved before reliable quantitative values can be obtained

SUMMARY

A series of 28 rats were given daily injections of 2 mg 17 hydroxy corticosterone (hydrocortisone) subcutaneously after the right tibia and fibula had been fractured

Histological specimens were stained with toluidine blue and the mast cells were studied

An increase in number was observed beginning from the 8th day and reaching a maximum between the 10th and the 16th day The formation of cartilage and bone was moderately delayed compared with non steroid—treated animals of earlier series Despite the delay in callus formation firm union of the fracture was ultimately obtained

The mast cells showed greater differences in size metachromatic properties and granulation than those in the previous group of untreated animals Mast cells are probably created through metachromatic transformation of fibrocytes

RESUME

Il a été administré quotidiennement des injections sous cutanées de 2 mg de 17 hydroxycorticosterone (hydrocortisone) à une série de 28 rats après fracturation des tibia et pérone droits

Des échantillons histologiques ont été colorés au bleu de toluidine et les mastocytes ont été examinés

Une augmentation de leur nombre a été observée à partir du 8ème jour atteignant le maximum entre le 10ème et le 16ème jour La for

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From the Department of Surgery Vaasa Central Hospital Vaasa Finland

FRACTURE HEALING AND MAST CELLS

III Action of Combined Growth Hormone and Thyrotropin

By

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Received 9 I 67

Variations in the number of mast cells in the periosteal callus of experimental fractures in rats untreated and under the influence of 17 hydroxy corticosterone have recently been demonstrated (*Lindholm R Lindholm S & Lukko* 1966 *Lindholm, S Lindholm R & Lukko* 1967)

The mast cells increase after thyrotropin medication (*Asboe Hansen* 1951) In the cheek pouch of the living hamster treated with thyrotropin and somatotropin a large number of well granulated mast cells were seen (*Wegelius & Asboe Hansen* 1956) Thyrotropin or somatotropin however did not influence the number of mast cells in the skin of dwarf mice (*Dyrbye Ahlqvist & Wegelius* 1959) New bone formation under the influence of growth hormone especially when combined with thyrotropin is vigorously stimulated (*Koskinen* 1959) No investigations on mast cells seem to have been carried out during hormonally stimulated regeneration of bone

MATERIAL AND METHODS

The materi l c n i ted f 30 white rats of both sexes we ghing 125 135 g at the tart f the experiment Th animals had been reared under the same physical n iiti r nd fed the usual labo at ry diet and tap water

Under ether ana thesia the right tibia and fibula were manually fractured All nim l r el e l daily 0 f IU (=30 till ia units) somat otr pin 1 and 0 1 IU (=0 1 U S P unit) thyr tr pin subcutane usly The animals were sacrificed and hi to l gical pecimens were taken on the days 1 2 3 4 5 6 8 9 12 15 16 18 19 22 ft fra turing Th pe imens consisted of callus tissue fr m the external site and ntr l spe imen were removed fr m the per osteum f the left tibia

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1 S m et n Ferring AB Malmö Sweden
Act ron Ferring AB Malmö Swe l n

5 Koskinen F (1959) *The repair of experimental fractures* Ann Chir Gynaec Fenn suppl 90 1–48
6 Lindholm R Lindholm S & Liukko P (1966) Fracture healing and mast cells The periosteal callus in rats (In press)
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8 Wegelius O., & Asboe Hansen G (1956) Hormonal effects of mast cells Studies on living connective tissue in the hamster cheek pouch Acta endocrin 2? 157–165

Histochemical and tracer studies may reveal disturbances in the mast cell metabolism of a nature which cannot be visualized by metachromatic staining alone In view of the constant finding of mast cells and their invariable multiplication in the callus tissue where endochondral ossification takes place it is anticipated that further studies using agents known to cause disturbances of osteogenesis e g the sweet pea (*Robinson & Bast* 1934) will be invaluable in unravelling the mechanisms whereby mast cells are involved in the healing of fractures

SUMMARY

A series of 30 rats were given daily injections of somatotropin and thyrotropin subcutaneously after the right tibia and fibula had been fractured Healing was stimulated and early mineralization of the callus cuff was demonstrated roentgenologically A typical increase in the number of mast cells in the differentiating blastema was noted the peak being reached 3–4 days earlier than in untreated rats The curve obviously parallels that of accelerated mineralization The absolute number of cells found in some approximate counts was of the same magnitude as in normal rats and somewhat lower than in rats on 17 hydroxycorticosterone medication

RESUME

Il a été administré à une serie de 30 rats des injections quotidiennes sous cutanées de somatotropine et de thyrotropine apres provocation de fractures du tibia et du perone droits La guerison de la fracture s'est trouvee stimulee et à l'examen radiologique il est apparu que le cal se minéralisait précocement Il a ete note une augmentation typique des mastocytes du blasteme qui se differenciaient La culmination fut atteinte 3 4 jours plus tot que chez les rats à l'etat normal La courbe est semble t il parallèle à celle de l'augmentation de la mineralisation Le nombre absolu des cellules obtenues par numeration indicative a été de la meme grandeur que chez les animaux normaux et parfois un peu plus bas que chez les animaux auxquels il etait administre une medication de 17 hydroxycorticosterone

ZUSAMMENFASSUNG

Nach Zerbrechen der rechten Tibia und Fibula wurden 30 Ratten täglich subcutane Injektionen vom Somatotropin und Thyreotropin ge

Roentgenograms were taken of both hind limbs. The mast cells were stained and counted in planes perpendicular to the periphery of the callus cuff according to a technique described previously (*Lindholm R., Lindholm S. & Liukko* 1966). An approximate count was made of the mast cells in the early (on the 4th and 6th days), middle (on the 8th and 12th days) and late phase (on the 15th and 16th days) of repair.

RESULTS

Palpable callus was demonstrated on the 4th day, and the fracture was clinically stable on the 15th day. The first signs of mineralization were visualized microradiographically on the 5th day. By the 12th day the entire callus showed signs of slight mineralization on the roentgenogram.

The mast cell counts showed the following number of cells: 4th day and 6th day 27 per mm² = 1925 per cu mm, 8th day 58 per mm² = 4135 per cu mm, 12th day 52 per mm² = 3708 per cu mm, 15th day 37 per mm² = 2638 per cu mm and 16th day 19 per mm² = 13[illegible] per cu mm. In the controls no variations were observed. The mast cells were situated in the mesenchymal parts of the callus and none could be seen in cartilaginous or osseous areas. Their distribution and localization appeared unequal and variable. The mast cells disappeared from view at the borderline of cartilaginous tissue, where the metachromatic stainability of the matrix generally increases. Morphologically the mast cells did not differ substantially from those in the periosteal callus under normal laboratory conditions.

DISCUSSION

The increase in the number of mast cells in the periosteal blastema undergoing differentiation seems to parallel the process of healing in general. Under the influence of 17-hydroxy-corticosterone there is a delay which almost corresponds to the delay of mineralization and consolidation of the fracture (*Lindholm S., Lindholm R. & Liukko* 1967). The action of growth hormone and thyrotropin somewhat accelerates the increase in number in comparison with the normal series. Despite the delay of healing, hydrocortisone does not decrease the number of mast cells; on the contrary, it causes a relative increase, a phenomenon probably secondary to degranulative or secretory insufficiency of the mast cells. Combined growth hormone and thyrotropin medication did not alter the absolute number of mast cells in any appreciable way as compared with the normal series.

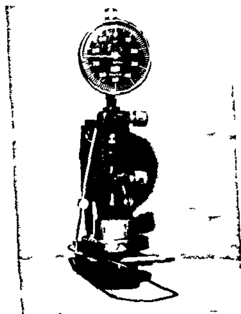


Figure 1 Micrometer used for thickness measurements

Specimens of reproducible size must be prepared in order to obtain quantitative data from tensile tests. The methods of preparation should not induce changes in the tissue.

The study of two variables (a) methods of preparation and (b) effect of environment on the water content of samples from the annulus fibrosus in regard to tensile behaviour is the purpose of this presentation.

MATERIAL AND METHODS

The study is based on human material. Autopsy subjects ranging from 20 to 3[illegible] years of age with normal intervertebral discs or showing minimal degenerative changes were used. The experiments were performed within 36 hours after death. The lumbar spines with their surrounding muscles and ligaments were placed in polyethylene bags, sealed immediately after removal and stored for short periods at +4° C.

Specimens from the anterior annulus were used. They were cut in samples 1 mm thick in the direction of the concentric sheets of the annulus using a stereo microscope in the early experiments and later with a freezing microtome.

Test samples were stamped out on a specially designed press and die assembly which cut rectangular shaped specimens [illegible] × 5 mm. In experiment number 3 a die which cut specimens 5 × [illegible] mm was used. The long axis of the samples was horizontally placed. These specimens were utilized for comparative paired ex

geben. Die Frakturheilung wurde dadurch stimuliert und die Callusmanschette zeigte röntgenologisch eine frühzeitige Mineralisation.

Im Blastem wurde eine typische Zunahme der Zahl der sich differenzierenden Mastzellen gefunden. Die Spitze wurde 3–4 Tage früher als bei Ratten, die sich in normalen Verhältnissen befanden, erreicht. Die Kurve geht augenscheinlich parallel mit der der Mineralisation. Die absolute Zellzahl, die durch einige Probezählungen erhalten wurde, war gleich der bei normalen Tieren und etwas niedriger als die bei Tieren, die mit 17-hydroxycorticosterone behandelt worden waren.

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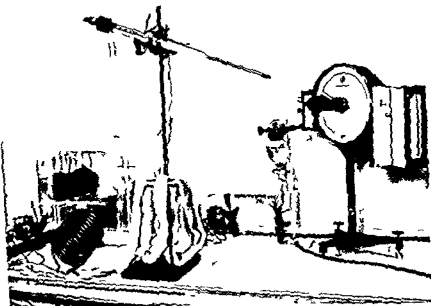


Figure 3 Contents of the chamber

A torsion balance whose accuracy was ± 0.2 mg was placed inside the box (Figures 2, 3)

Samples were tested in groups of five. They were introduced at one minute intervals and weighed initially and every fifteen minutes for one hour

Tensile test Tensile tests were performed on an Instron TTBM tensile tester calibrated to an accuracy of ± 0.5 per cent

Sliding of the specimens from the clamps during application of tension presented a major problem. Special jaw faces were developed with matching serration at 0.75 mm intervals. These faces were fitted in the Instron model B pneumatic clamp. Tests were performed at 65 per cent relative humidity 21 C temperature. Specimens were cycled twice to a load of 0.2 kg at rate of elongation of 0.5 cm m

From the load elongation diagrams the following values were calculated: Elongation at 0.2 kg, permanent deformation and energy dissipation represented by the area under the curve. These data were used only for paired comparisons to test the effect of a variable on the sample. They were not meant for quantitative material evaluation

STATISTICAL METHODS

Standard statistical methods were used

The 5 per cent level of significance was applied

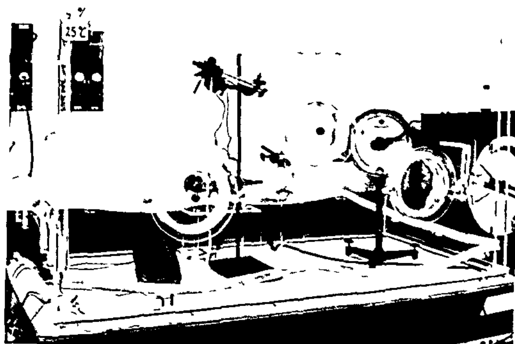


Figure 2 Chamber used in controlled humidity and temperature experiments

periments to test the effect of variables where no stress strain relations were derived

Thickness measurements were made by means of a specially constructed dial gage designed to measure with a foot pressure of 10 grams distributed over the specimen surface area with an accuracy of ± 0 005 mm (Figure 1)

A *Swelling experiments* Specimens were weighed fre h in an analytical balance to an accuracy of ± 0 05 mg and placed in beakers containing the respective solutions at room temperature They were removed at 5 min 30 min 1 hr 3 hr 5 hr 7 hr 24 hr and 32 hrs and weighed The surface were blotted for five seconds to remove excess surface liquid before weighing Dry weights were obtained by oven drying at 60 C for four days and weighing subsequently

B *Air exposure experiments* Exposure of samples to different atmospheres of controlled temperature and humidity was made in a specially designed box with a double wall to provide dead spa e insulation and openings fitted with plastic gloves to allow work inside of the chamber (9)

Humidity was produced by blowing air over a water container and drying accomplished with ilica gel A psychrometer constructed with temperature sensitive diodes was used for humidity control

Changes in temperature were induced with an electric heater and a cooling coil which circulated tap water Temperature control was provided by means of a contact thermometer and a relay system

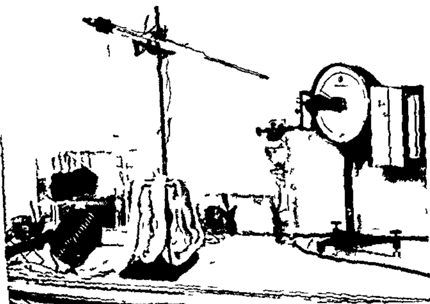


Figure 3 Contents of the chamber

A torsion balance whose accuracy was ± 0.2 mg was placed inside the box (Figures 2, 3).

Samples were tested in groups of five. They were introduced at one minute intervals and weighed initially and every fifteen minutes for one hour.

C. *Tensile test.* Tensile tests were performed on an Instron TTBM tensile tester calibrated to an accuracy of ± 0.5 per cent.

Gliding of the specimens from the clamps during application of tension represented a major problem. Special jaw faces were developed with matching serrations at 0.75 mm intervals. These faces were fitted in the Instron model B pneumatic clamp. Tests were performed at 65 per cent relative humidity, 21° C. temperature. Specimens were cycled twice to a load of 0.2 kp at a rate of elongation of 0.5 mm/min.

From the load-elongation diagrams the following values were calculated: Elongation at 0.2 kp load, residual deformation and energy dissipation represented by the area under the curves. These data were used only for paired comparisons to test the effect of a variable on the sample. They were not meant for quantitative material evaluation.

STATISTICAL METHODS

Standard statistical methods were used.

The 5 per cent level of significance was applied.

EXPERIMENTS AND RESULTS

1. *Changes in Water Content Following Death*

In experiments using autopsy material there is a time lag between death and sampling. To evaluate changes in water content during that period the following experiment was performed. Two adult rabbits were used. Their lumbar and lower thoracic intervertebral discs, ten for each animal, were distributed at random in two groups of ten discs each. Ten specimens were removed immediately after sacrificing the animals. Care was taken not to disturb the ligaments and muscles surrounding the rest of the spine. The incisions were closed and the animals stored at 4° C for 48 hours. At the end of this period the other ten discs were removed. Samples were weighed immediately after removal, vacuum dried for 48 hours and weighed again. Student's test was used to determine the significance of differences in water content between the two groups.

The data is summarized below.

Table 1

Water content of samples	Fresh	48 hours	T test
Wet-dry weight / Wet weight	0.73675 ± 0.00314	0.73699 ± 0.00633	0.0272 not significant
No. of samples	10	10	

Wet weight minus dry weight divided by wet weight.

The differences were not significant.

Conclusion. No change was evident in water content of samples within 48 hours after death.

2. *Effects of Immersion in Different Solutions*

Prior and during mechanical tests samples from collagenous structures are often immersed in some type of aqueous solution. Connective tissues, however, have a great avidity for water and swelling will occur.

Swelling characteristics of samples from the annulus fibrosus in four different media was investigated. Distilled water, 0.9 per cent sodium chloride solution, human plasma, rheomacrodex.

40 samples from 5 lumbar spines were used. They were divided in

a random fashion in four groups of ten samples each and weighed over a period of 32 hours after immersion in the respective solutions in room temperature as described previously

The data is summarized below

Table 2

Solution	Average Orig weight gr	Average swollen weight gr	No of samples	% increase
Dist water	0 10688 ± 0 00596	0 25513 ± 0 02013	10	138 70
0 9 % Na chloride	0 10162 ± 0 00210	0 18710 ± 0 00316	10	80 18
Human plasma	0 09681 ± 0 00210	0 17294 ± 0 00271	10	78 63
Rheomacrodex	0 09200 ± 0 00199	0 19265 ± 0 00663	10	109 40

The difference between original and swollen weights were highly significant in all instances

In Figure 4 accrued weight has been plotted as a function of accumulated time of swelling

In all cases the rate of swelling was rapid during the first minutes

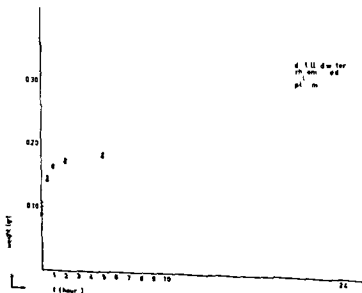


Figure 4 Swelling of samples in different media

decreasing then progressively until a state of equilibrium was reached. Water uptake was completed within two hours in distilled water and within five hours in the other media investigated.

Conclusions. Considerable swelling was induced in all samples by the different media. Water uptake was higher and faster in distilled water. Concomitant with their gain in weight, the size and shape of the specimens changed so that thickness and width measurements became difficult and inaccurate.

3. Changes in Tensile Characteristics Induced by Swelling

Eleven samples were prepared from the anterior annulus. Tensile tests were performed in air. Samples were then immersed in 0.9 per cent sodium chloride solution for five hours to allow full swelling and tested again immersed in sodium chloride solution in a plastic receptacle adapted to the clamps of the machine.

The evaluated data is summarized in Table 3.

Table 3

	Elongation mm	Residual deformation mm	Energy dissipation kp mm	No of samples
Tested in air	1.132 ± 0.064	0.266 ± 0.022	0.04787 ± 0.00542	11
After swelling in 0.9 % Na chloride	1.863 ± 0.103	0.560 ± 0.042	0.12091 ± 0.01516	11
T test	11.147	6.455	5.535	

The differences were significant. The samples in sodium chloride solution exhibited more deformation, decreased recoverability and more energy dissipation.

Conclusion. These experiments showed that significant alterations in dimensions and in mechanical characteristics were induced by use of immersion techniques. For this reason they were discarded as a reasonable method of investigation.

4. Exposure of Samples to Controlled Temperature and Humidity

The purpose of these experiments was to determine if the water content of samples could be kept constant in air.

45 samples from the anterior annulus of discs from three different lumbar spines were removed and distributed at random in nine groups of five samples each to be tested under one of the following conditions

Temp 25 C, rel humid 70 per cent 80 per cent and 90 per cent
Temp 30 C, rel humid 70 per cent 80 per cent and 90 per cent
Temp 37 C rel humid 60 per cent 70 per cent and 80 per cent

For each group the samples were exposed to the corresponding atmosphere and weighed every 15 minutes during one hour as previously described

Progressive loss of weight occurred in all cases

A straight line relation between loss of weight and time was assumed for the 60 minutes interval A regression coefficient was calculated for each curve and used as a variable in an analysis of variance to test differences between relative humidities at a given temperature

Table 4

Temp 25 C	A ge re r c eff	± st err	% decr in 60 min
Rel humid 70	—0 41460	0 01708	11 79
Rel humid 80	—0 30337	0 00447	5 95
Rel humid 90 %	—0 13326	0 00 65	2 28

Analysis of Variance for temp 25 C

Source of variation	DF	SS	MS	F
Between groups	2	0 009	0 10042	179 32
Within groups	12	0 00632	0 00056	
Total	14	0 20767		

The change in values which corresponded to differences of relative humidity at a given temperature were highly significant

Water was lost at a higher rate in the low humidity sets and at 37 C Plotting the regression coefficients for each temperature group as a function of relative humidity (Figure 5) it is evident that a zero

Table 5

Temp 30 C	Av ge regr coeff	± st err	% decr in 60 min
Rel humid 70 %	—0 41186	0 01319	10 37
Rel humid 80 %	—0 30010	0 00199	6 90
Rel humid 90 %	—0 13090	0 00565	3 0[illegible]

Analysis of Variance for temp 30 C

Source of variation	DF	SS	MS	F
Between groups	2	0 20009	0 10004	28 85
Within groups	12	0 00428	0 00035	
Total	14	0 20437		

Temp 37 C	Av ge regr coeff	± st err	% decr in 60 min
Rel humid 60 %	—1 04153	0 02502	18 45
Rel humid 70 %	—0 61148	0 01922	12 09
Rel humid 81 %	—0 32667	0 00623	7 32

Analysis of Variance for temp 37 C

Source of variation	DF	SS	MS	F
Between groups	2	1 29813	0 64906	218 3
Within groups	12	0 03567	0 00297	
Total	14	1 33380		

value that is to say no loss of water would be reached at a relative humidity of 100 per cent

Conclusion To avoid or minimize the loss of water the preparation and handling of samples must be performed in an atmosphere of 100

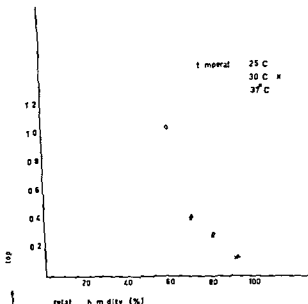


Figure 5 Regression coefficients (slope) of loss of weight vs time plotted against relative humidity

per cent relative humidity preferably at a temperature of 25 C or lower

5 Effect of Air Drying on Some Tensile Properties

For technical reasons it may be difficult to maintain a relative humidity of 100 per cent while performing the tensile tests or the actual performance of the test may involve a very short period of air exposure and therefore a minimal loss of water

The following experiment was performed to determine the effect of loss of water on mechanical properties under controlled conditions Fifteen samples were prepared from the anterior peripheral annulus of four lumbar discs from the same spine

They were tested in tension in air at a relative humidity of 65 per cent and a temperature of 21 C The samples were tested within 30 seconds after ten minutes and after one hour

The differences were not significant after ten minutes but changes were present in the one hour test

Conclusion Samples can be tested at 65 per cent relative humidity

Table 5

Temp 30 C	Avge regr coeff	± st err	% decr in 60 min
Rel humid 70 %	—0.41186	0.01319	10.37
Rel humid 80 %	—0.30010	0.00199	6.90
Rel humid 90 %	—0.13090	0.00[illegible]65	3.0[illegible]

Analysis of Variance for temp 30 C

Source of variation	DF	SS	MS	F
Between groups	2	0.20009	0.10004	285.85
Within groups	12	0.00428	0.0003	
Total	14	0.20437		

Temp 37 C	Avge regr coeff	± st err	% decr in 60 min
Rel humid 60 %	—1.04153	0.0[illegible]0[illegible]	18.45
Rel humid 70 %	—0.61148	0.01922	12.09
Rel humid 81 %	—0.32667	0.00623	7.3[illegible]

Analysis of Variance for temp 37 C

Source of variation	DF	SS	MS	F
Between groups	2	1.29813	0.64906	218.53
Within groups	12	0.03567	0.00297	
Total	14	1.33380		

value that is to say no loss of water would be reached at a relative humidity of 100 per cent

Conclusion To avoid or minimize the loss of water the preparation and handling of samples must be performed in an atmosphere of 100

Data is summarized in Table 7

The differences were not significant

Conclusion Freezing under CO_2 snow and thawing at a relative humidity of 100 per cent did not alter the mechanical behaviour of the samples These experiments justify the use of a freezing microtome for sectioning of the samples

CONCLUSIONS

In standardizing methods of preparation and testing for the study of mechanical properties of collagenous structures the most difficult problem encountered is to avoid alterations in the water content of the samples

Water tissue relations have been postulated as critical in determining deformation characteristics of biological materials (10) Connective tissues have great avidity for water and swelling will result when immersed in aqueous solutions (11 12) We have shown this process in the annulus fibrosus The deformation characteristics were significantly altered with swelling The samples became more extensible exhibited decreased recovery and increased energy dissipation Therefore immersion techniques were discarded

The water content of the annulus fibrosus is high Pushel reported values between 70 to 78 per cent according to age and degeneration characteristics (13)

Most of this water is loosely bound and for that reason specimens dry rapidly when exposed to air Their tensile properties are altered under these circumstances (14) The problem is magnified as the sample size decreases When the sample dimensions are small the environmental factors become critical and must be controlled

Water vapour diffuses to the specimen surface along a pressure gradient and the slope of this gradient will be a major factor in determining the rate of vapour transfer This rate is also dependent on temperature The sample can be coated to retard evaporation but variables due to the coating material will be introduced The alternative is to eliminate the pressure gradient providing an atmosphere with a relative humidity of 100 per cent This investigation has led us to prepare and handle the samples in an atmosphere of 100 per cent relative humidity at a temperature of 21 C

In this study on human autopsy material no control over postmortal changes was possible In rabbits knee ligaments protected from air

at 21° C if the test involves a short period of time. For longer tests as in stress relaxation, repetitive cycling or creep, a humidity of 100 per cent is necessary.

Table 6

Time of air exposure	Elongation mm	Residual deformation mm	Energy dissipation kp mm	No. of samples
30 sec	1.051 ± 0.071	0.252 ± 0.033	0.0242 ± 0.0018	16
10 min	1.043 ± 0.058	0.294 ± 0.022	0.0259 ± 0.0012	16
60 min	0.893 ± 0.114	0.589 ± 0.109	0.0368 ± 0.0030	16
T Test	7.39	8.73	16.94	

The difference between 30 seconds and 10 minutes were not significant, the differences between 30 seconds and 60 minutes were significant.

Table 7

	Elongation mm	Residual deformation mm	Energy dissipation kp/mm	No. of samples
Fresh	1.352 ± 0.146	0.101 ± 0.012	0.0381 ± 0.0049	10
After freezing	1.217 ± 0.135	0.096 ± 0.010	0.0316 ± 0.0041	10
T test	0.601	0.908	0.900	
	Elongation mm	**Residual deformation mm**	**Energy dissipation kp/mm**	**No. of samples**
Fresh	1.092 ± 0.090	0.082 ± 0.028	0.0318 ± 0.0029	11
After freezing	1.009 ± 0.094	0.073 ± 0.010	0.0318 ± 0.0029	11
T test	0.619	0.475	–	

6. *Effects of Freezing on some Tensile Properties*

To obtain quantitative informations samples of reproducible constant dimensions are essential. It was thought that a freezing microtome could provide specimens of constant thickness.

From two lumbar spines samples were obtained by dissection and divided into two experiments similar in characteristics. The samples were first tested in tension, then frozen under a carbon dioxide snow stream and allowed to thaw in a high humidity atmosphere. They were then retested.

RÉSUMÉ

Il est décrit une série d'expériences tendant à standardiser les tests de résistance à la tension de spécimens d'anneaux fibreux humains du disque intervertébral La teneur en eau dans les spécimens in situ reste constante dans les 48 heures qui suivent le décès

Une immersion dans une solution aqueuse entraîne un gonflement et pas de modifications appréciables du spécimen

Les spécimens exposés à l'air dans des conditions d'humidité relative et de température différentes perdent en toutes circonstances leur eau l'équilibre n'est rétabli qu'à 100 pour cent d'humidité relative

Les modifications mécaniques entraînées par le séchage de l'air dont l'humidité relative est de 65 pour cent et la température 21 C pendant dix minutes sont insignifiantes

La congélation sous neige CO et le rapide dégel à un taux d'humidité relative de 100 pour cent dans des conditions reproduisant celles d'un microtome congélateur n'ont pas altéré le comportement mécanique des spécimens

ZUSAMMENFASSUNG

Um eine Standardisierung der Dehnungsuntersuchungen in Proben vom Anulus fibrosus zu erreichen ist eine Serie von Experimenten gemacht worden

Der Wassergehalt von Proben die in situ gelassen worden waren verblieb während 47 Stunden nach dem Tode konstant

Eintauchen in Wasserlösungen verursachte eine bedeutende Schwellung der Probestücke mit signifikanten Veränderungen ihrer Stärke

Probestücke die in Luft verschiedener Feuchtigkeit und Temperatur exponiert wurden verloren immer Wasser Ein Ausgleich wurde bei 100 prozent relativer Feuchtigkeit erreicht

Mechanische Veränderungen die während 10 Minuten durch Lufttrocknen bei 65 prozent relativer Feuchtigkeit hervorgerufen worden waren zeigten keine Signifikanz

Beim Einfrieren unter CO-Schnee und schnellem Auftauen bei 100 prozent relativer Feuchtigkeit —wie es bei Verwendung eines Gefriermikrotoms gemacht wird wurden die mechanischen Verhältnisse nicht verändert

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exposure. Viidik et al. found no alterations in mechanical properties up to ninety-six hours after death (15). Our study on the intervertebral discs of rabbits showed no alterations in water content forty-eight hours following death. These results support the use of autopsy specimens.

Our aim throughout these experiments has been to maintain the water content of the samples at the level present when removed from the body. Although this approach may not resemble the in vivo conditions where an active water transfer may be present when the tissue deforms, it prevents the highly significant differences induced in the characteristics of the specimens by the immersion methods.

Freezing was used for the preparation of samples. The formation of ice from water is the most important physical change occurring when tissue is carried to low temperature. Injury may then be produced on mechanical or chemical basis and the time element will be of importance (16).

Freezing to the temperature of CO_2 snow (—78° C) and rapid thawing at 100 per cent relative humidity did not alter the tensile characteristics of the samples. Therefore a freezing microtome was used for sectioning the tissue.

The experimental procedures analysed in this publication provide the background for the methods adopted in the study of mechanical characteristics of the annulus fibrosus.

SUMMARY

A series of experiments is described used to standardize tensile tests on samples from human annulus fibrosus.

The water content of samples in situ remained constant up to 48 hours after death.

Immersion in aqueous solution induced considerable swelling in the samples and significant changes in their tensile behaviour.

Samples exposed to air at different relative humidities and temperatures lost water in all circumstances. Equilibrium was shown to occur at 100 per cent relative humidity.

Mechanical changes induced by air drying at 65 per cent relative humidity, temperature 21° C for 10 minutes were not significant.

Freezing under CO_2 snow and rapid thawing at 100 per cent relative humidity under conditions simulating a freezing microtome did not alter the mechanical behaviour of the samples.

Acta orth. scandinav. 38, 163-173, 1967

From the Clinic for Orthopaedics and Traumatology (Head: Professor K. E. Kallio)
and the Department of Forensic Medicine (Head: Professor U. Uotila)
University of Helsinki

EFFECT OF COMPRESSION ON THE HEALING OF SUBCAPITAL OSTEOTOMIES OF THE FEMORAL NECK AND ON THE AVASCULARIZED FEMORAL HEAD

An Experimental Study on Adult Rabbits

By

P. Rokkanen and P. Slätis

Received 18.1.67

Fractures in cancellous bone unite without any intermediate formation of cartilaginous callus and without any marked degree of periosteal reaction. Healing is accelerated if the bony surfaces are pressed against each other by some appropriate device. This principle has been successfully applied in arthrodesis and in the treatment of fractures (*Charnley & Baker* 1952, *Charnley* 1953, *Gasser* 1965). The results are mostly good when both cancellous bone fragments are adequately vascularized. The prospects are poorer when the blood supply of one of the fragments is disturbed, as is the case in subcapital fractures of the femoral neck. In these cases, aseptic necrosis of the femoral head and pseudarthrosis of the neck are of common occurrence. In order to improve the prognosis, a compression technique has been used (*Charnley, Blockey & Purser* 1957, *Charnley* 1961), apart from various types of sliding nails. The results have been promising.

There are few data concerning the effect of compression on the healing of osteotomies in the presence of one avascular fragment. Better knowledge concerning this problem would clarify the possible usefulness of compression in the treatment of fractures of the femoral neck.

In continuation of previous experiments on osteotomies of the femoral neck (*Rokkanen, Slätis & Laine* 1965, *Slätis & Rokkanen* 1966), the

This study was aided by an institutional grant from the Sigrid Jusélius Foundation, Helsinki, to the Department of Forensic Medicine, University of Helsinki.

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frontal plane one half was taken for histological investigation and the other half was fixed in methyl metacrylate for oxytetracycline (OTC) fluorescence microscopy

The animals were given 50 mg of oxytetracycline per kg body weight for three consecutive days before being killed

After EDTA decalcination the histological specimens were stained by Weigert van Gieson haematoxylin and the Alcian blue methods

The methyl metacrylate specimens were sawed and ground to sections 100 μ in thickness for the purpose of microscopic fluorescence studies

RESULTS

In the compression group one infection and two bolt breaks occurred in the control group three infections and five bolt breaks In the analysis of the results the infected animals are omitted but the cases with bolt breaks are assessed

The following observations were made on the healing of the osteotomies and the changes of the femoral heads

One week after operation 4/6 osteotomies in the *compression group* were firm In one case roentgenography revealed that the spring was not maximally compressed

Histologically granulation tissue and formation of new bone were observed principally in the area of cancellous bone in the femoral neck[1] The cancellous bone of the femoral head was mainly nuclear whilst the cancellous spaces were poor in cells

The OTC fluorescence was strongest in the internal callus of the femoral neck In the femoral head a slight uptake was observed laterally close to the osteotomy and in one specimen in the whole area of the osteotomy but not in any other site (Figure 3 a)

In the *control group* 1/6 osteotomies were firm Roentgenologically the contact was found to be poor in three animals

Histologically the external callus formation was more exuberant than in the compression group In contrast to the compression group no regeneration was observed in the femoral head

The OTC uptake in the femoral neck was equally strong in both groups

Three weeks after operation the osteotomy was firm in 2/6 animals

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[1] What follows regeneration (granulation tissue and formation of new bone) in the area of cancellous bone are called internal callus External callus is used to designate the callus growing on the outer surface of the femoral neck towards the femoral head and sheathing the osteotomy



Figure 1



Figure 2

Figure 1 Roentgenogram taken one week after osteotomy of the femoral neck The compressing device is in place The line of osteotomy is visible

Figure 2 Roentgenogram taken 12 weeks after osteotomy of the femoral neck The femoral head is flattened and its density is increased The osteotomy has united

um of this study was to investigate the effect of compression on the healing of osteotomy of the femoral neck and on the changes in the head

MATERIAL AND METHODS

In the experiments 47 adult rabbits of both sexes were used The left hip joint was exposed by a posterolateral incision the ligamentum teres was severed the femoral head was dislocated and the trochanteric muscles were detached The femoral neck was osteotomized with an electrical saw so as to become completely free The femoral head was replaced and fixed with a transcervical bolt In the experimental group which comprised 24 animal continuous compression was produced by the application of a spring between the head of the bolt and the trochanter (Figure 1) When maximally compressed the spring yielded a pressure on the osteotomized bone of 55 g per square millimetre In the control group consisting of 23 animals only fixation with a bolt was used

The animals were killed 1 3 6 and 12 weeks after the operation The femoral heads on both the operated and the unoperated side were dissected out and roentgenographed The proximal parts of the femora were split into two halves in the

frontal plane one half was taken for histological investigation and the other half was fixed in methyl metacrylate for oxytetracycline (OTC) fluorescence microscopy

The animals were given 50 mg of oxytetracycline per kg body weight for three consecutive days before being killed

After EDTA decalcination the histological specimens were stained by Weigert van Gieson's haematoxylin and the Alcian blue methods

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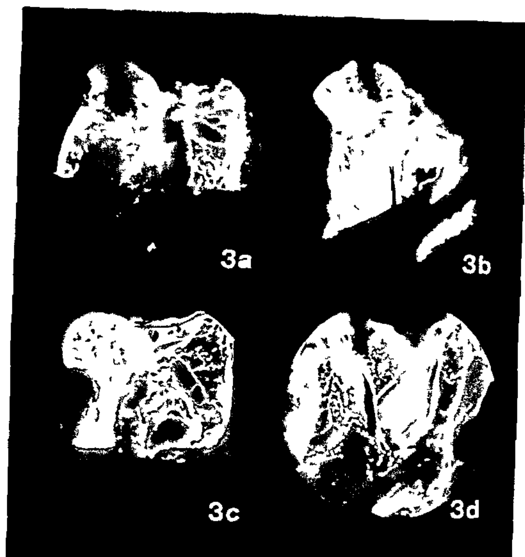


Figure 3a Fluorescence micrograph taken one week after osteotomy of the femoral neck and application of compression The strongest OTC uptake is seen in the femoral neck in the internal callus Slight uptake is discernible in the femoral head in the vicinity of the osteotomy

Figure 3b Three weeks after the osteotomy The strongest OTC uptake is still observed in the femoral neck Close to the osteotomy a weaker fluorescence is seen in the femoral head

Figure 3c Six weeks after the osteotomy The OTC uptake is strong in the femoral neck and of the same strength over an area extending into the middle of the femoral head

Figure 3d Twelve weeks after the osteotomy The OTC uptake is weaker in the femoral head and neck than in the previous group Note the derangement and flattening of the femoral head

in the *compression group* Roentgenologically two bolt breaks were detected

Histologically two cases showed bony union of the lateral part of the femoral head and the neck Regeneration proceeded from the neck into the head mainly by the internal route Animals with movable femoral heads had a more abundant external callus The femoral head was more clearly ischaemic than in the foregoing group Granulation tissue was observed in the head in the vicinity of the osteotomy

The OTC fluorescence was still strongest in the femoral neck After union of the osteotomy the uptake began to extend to the femoral head (Figure 3 b)

In the *control group* all femoral heads were movable One bolt break was observed roentgenologically

Histologically the internal bone formation was found to have remained stationary at the level of the osteotomy and the external callus was more conspicuous than in the compression group On the other hand the femoral heads with their enlarging necrotic areas resembled those in the animals of the compression group

The OTC fluorescence revealed a more exuberant external callus formation than in the compression group In two cases weak OTC uptake was observed in the femoral head adjacent to the osteotomy but in the remainder no uptake was noted in the head

Six weeks after operation the osteotomy was firm in 5/6 animals in the *compression group* A roentgenological increase in density was observed in the femoral neck

Histologically bony union of the fragments could be observed An area of uniform regeneration extended to the *middle of the femoral head* In the latter the cancellous spaces were empty and the subchondral cancellous bone was entirely anuclear In the articular cartilage clusters of abnormal cells were seen and fibrocartilage grew like a sheath from the sides over the articular surface signifying degeneration

The uptake of fluorescing material was brisk in the femoral neck and extended as far as the middle *of the head* only the dome of the head being still devoid of fluorescence (*Figure 3 c*)

In the *control group* the osteotomy was firm in 3/5 cases Two bolt breaks were detected roentgenologically

Histologically vigorous internal callus formation was observed in the femoral neck and a more abundant external callus than in the compression group extended to the femoral head The degeneration of

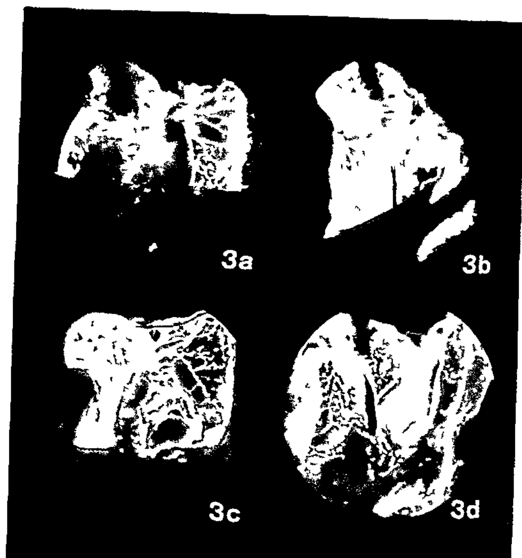


Figure 3 a Fluorescence micrograph taken one week after osteotomy of the femoral neck and application of compression The strongest OTC uptake is seen in the femoral neck in the internal callus Slight uptake is discernible in the femoral head in the vicinity of the osteotomy

Figure 3 b Three weeks after the osteotomy The strongest OTC uptake is still observed in the femoral neck Close to the osteotomy a weaker fluorescence is seen in the femoral head

Figure 3 c Six weeks after the osteotomy The OTC uptake is strong in the femoral neck and of the same strength over an area extending into the middle of the femoral head

Figure 3 d Twelve weeks after the osteotomy The OTC uptake is weaker in the femoral head and neck than in the previous group Note the derangement and flattening of the femoral head

this principal route of healing an external callous cuff develops round the osteotomy growing from the soft parts of the femoral neck to the necrotic head (*Slätis & Rokkanen* 1966) This external callus leads to fixation of the osteotomy and also participates in the revascularization of the head The present study disclosed that the poorer the fixation of the osteotomy the more important was the part played by the external callus in the process of healing In cases where internal fixation was adequate only slight external callus was observed as healing occurred directly through the cancellous bone

The fixation of the femoral head with a compressing device increased the stability of the osteotomy and led to a better rate and frequency of union After omission of the compression bolt breaks occurring during the experiment (7/43) and the animals killed after one week the frequency of union was 12/15 during 3 12 weeks in the compression group against 5/10 in the control group The compressive force and the frequency of union in the compression group correspond to the data reported by Charnley in human subjects Forgon & Bornemisza (1963) also demonstrated a favourable influence of compression on the healing of experimental osteotomies of the femoral neck in dogs

The femoral head collapsed 6 12 weeks after osteotomy had been performed At that time the osteotomy had united and the ingrowth of connective tissue had partly reached the dome of the head The collapse was marked in the compression group and it seems obvious that continuous compression easily leads to derangement of the femoral head The shape of the head remained unchanged as long as it was entirely necrotic and the subsequent collapse coincided with the regenerative process The results are consistent with Charnley's observation that compression leads to an increased degree of collapse of the femoral head and neck

The articular cartilage remained histologically unchanged during the first three weeks but then degenerated Obviously the cartilage remains sound for quite a long time nourished by the synovial fluid but degenerates as the process of regeneration reaches the subchondral area In this connection it is interesting to recall a comment by Scott (1964) to the effect that after a fracture of the femoral neck has healed in a human subject it would often be advantageous if the head remained necrotic

The results of these experiments are depicted in Figure 4

Compression obviously has to be used with good judgement in cases in which one of the cancellous bone fragments is necrotic it tends to

the femoral head and the articular cartilage corresponded to what was observed in the compression *group*.

The OTC uptake was strong in the femoral neck in both the internal and external callus but extended into the *femoral head only in two* animals.

Twelve weeks after operation all five osteotomies in the *compression group* were firm. Roentgenologically the femoral head was flattened in four and showed increased density in three animals (Figure 2). The osteotomy had united in all cases.

Histologically marked invasion of granulation tissue extended to the articular cartilage. The original cancellous bone in the femoral head was completely necrotic. The articular cartilage was covered with fibrocartilage and in part completely destroyed.

The OTC fluorescence in the femoral neck was weaker than in the *foregoing group*. A strong uptake was observed in the whole of the femoral head (Figure 3 d).

In the *control group* the osteotomies were firm in 2/4 animals. In two cases a bolt break had occurred. Roentgenologically no obvious flattening or increased density was observed.

Histologically marked regeneration of the femoral neck extended to the subchondral area of the femoral head in two cases. In two animals bony union had occurred. The cancellous bone in the femoral head was anuclear and the articular cartilage was completely degenerated as in the compression group.

The OTC uptake was still strongest in the neck. It extended into the subchondral area of the femoral head only in two cases.

DISCUSSION

In the rabbit capsulectomy of the hip joint causes only slight degeneration of the femoral head. Partial osteotomy of the femoral neck produces greater changes. As a result of total osteotomy necrosis of the head invariably develops and in these cases the ligamentum teres does not contribute to the regeneration of the femoral head (*Rokkanen* 1962, *Rokkanen, Slätis & Laine* 1965, *Slätis & Rokkanen* 1966). Hence it seems obvious that the femoral head of the rabbit is principally vascularized through the cancellous bone.

In the rabbit healing of an unfixed osteotomy of the femoral neck is brought about by direct bone formation in the osteogenic tissue growing from the neck into the devascularized head. In addition to

this principal route of healing an external callous cuff develops round the osteotomy growing from the soft parts of the femoral neck to the necrotic head (*Slätis & Rokkanen* 1966) This external callus leads to fixation of the osteotomy and also participates in the revascularization of the head The present study disclosed that the poorer the fixation of the osteotomy the more important was the part played by the external callus in the process of healing In cases where internal fixation was adequate only slight external callus was observed as healing occurred directly through the cancellous bone

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In the rabbit, capsulectomy of the hip joint causes only slight degeneration of the femoral head. Partial osteotomy of the femoral neck produces greater changes. As a result of total osteotomy necrosis of the head invariably develops and in these cases the ligamentum teres does not contribute to the regeneration of the femoral head (*Rokkanen* 1962, *Rokkanen, Slätis & Laine* 1965, *Slätis & Rokkanen* 1966). Hence it seems obvious that the femoral head of the rabbit is principally vascularized through the cancellous bone.

In the rabbit healing of an unfixed osteotomy of the femoral neck is brought about by direct bone formation in the osteogenic tissue growing from the neck into the devascularized head. In addition to

SUMMARY

The effect of compression on the healing of osteotomies of the femoral neck and on the changes in the femoral head was studied in 47 adult rabbits. The left femoral neck was osteotomized. In 24 animals the osteotomy was fixed with a transcervical bolt in order to produce compression with the aid of a spring. In 23 animals used as controls only bolts were applied without compression. The animals were killed 1–12 weeks after the operation. Specimens were examined roentgenologically, histologically and by the oxytetracycline labelling technique.

Compression was found to yield better fixation of the osteotomy leading to more favourable results as regards the rate and frequency of union. Healing started from the femoral neck and proceeded principally by internal callus formation across the osteotomy to the femoral head. On the other hand, in the poorly fixed osteotomies the external callus played a relatively greater part.

The shape of the femoral head remained unaltered as long as it was necrotic. Subsequent collapse of the head started 6–12 weeks after osteotomy as a result of revascularization and the resorption of bone associated with regeneration. The collapse was more complete in the compression group.

It is concluded that compression osteosynthesis of a fracture of cancellous bone in which one fragment is necrotic promotes union but easily leads to derangement of the necrotic fragment in the late stages of repair.

RÉSUMÉ

L'effet de la compression sur la guérison des ostéotomies du col fémoral et sur les modifications de la tête fémorale a été étudié chez 47 lapins adultes. Le col fémoral gauche a été sectionné. Chez 24 animaux l'oséotomie a été fixée par une vis transcervicale afin de produire un effet de compression à l'aide d'un ressort. Chez 23 animaux de contrôle on posa seulement la vis, mais sans compression. Les animaux furent sacrifiés entre 1 et 12 semaines après l'opération. Les spécimens ont été examinés radiologiquement, histologiquement et au moyen de la technique du label à l'oxytetracycline.

On a constaté que la compression donne une meilleure fixation de l'ostéotomie et conduit à des résultats plus favorables par rapport au taux et à la fréquence de la soudure. La guérison a commencé du col fémoral en progressant principalement par la formation de cal interne à travers l'ostéotomie jusqu'à la tête fémorale. D'un autre côté, dans

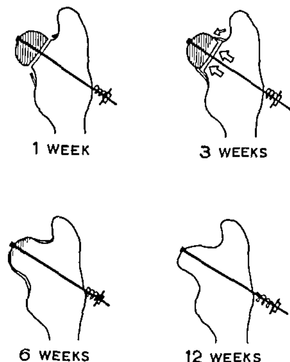


Figure 3 The healing of a subcapital osteotomy of the femoral neck and the changes occurring in the femoral head after application of a compressive device The femoral head is rendered completely devoid of vascular supply —One week after the osteotomy no uptake of fluorescing material can be detected as a sign of seriously impaired vascularity —Three weeks after the osteotomy ingrowth of fibrous tissue and formation of new bone are clearly seen in the femoral head adjacent to the ostetomy The main route of regeneration is through the cancellous bone (arrows) In addition external callus is adhering to the margin of the head Through this a minor degree of regeneration takes place —At six weeks most osteotomies have healed The zone of new bone formation extends to the middle of the femoral head At the time the breakdown of the trabecular structure starts Derangement of the femoral head proceeds as granulation tissue grows towards the subchondral area —At twelve weeks the osteotomy usually is united Regeneration has reached the dome of the head which frequently is flattened and like the femoral neck increased in density The articular cartilage has largely been replaced by fibrocartilage

lead to collapse of the necrotic fragment and structural derangement in the last stages of repair Since on the other hand compression clearly accelerates the healing of the osteotomy and since collapse occurs only after the osteotomy has healed the theoretically best method would be to remove the compressing device after healing has occurred but before collapse has taken place The adequate operative technique and the optimal moment for removal of the compressing device are however questions which still have to be settled

lung aber eine strukturelle Unordnung des nekrotischen Knochenfragmentes mit sich bringt

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les osteotomies ou la fixation n'est pas tres bonne le cal externe joue un role relativement plus important

La forme de la tete femorale est restee inchangees aussi longtemps qu'elle etait necrotique. Un collapsus subsequent de la tete est intervenu 6 a 12 semaines apres l'osteotomie comme un resultat de la revascularisation et de la resorption de l'os associees a la regeneration. Le collapsus etait plus complet dans le groupe a compression.

Il est conclu que l'osteosynthese de compression d'une fracture d'os spongieux dans laquelle l'un des fragments est necrotique favorise la soudure mais peut facilement conduire a une alteration du fragment necrotique dans le dernier stade de la restauration.

ZUSAMMENFASSUNG

Die Kompressionswirkung auf die Heilung einer Osteotomie des Schenkelhalses und auf die Veranderungen des Schenkelkopfes wurde bei 47 erwachsenen Kaninchen studiert. Der linke Schenkelhals wurde osteotomiert. Bei 24 Tieren wurden die Osteotomieflachen durch einen transcervikalen Bolzen fixiert, um eine Kompression durch eine Feder zustandezubringen. Bei 23 Tieren, die zur Kontrolle verwendet wurden, wurde nur ein Bolzen ohne Kompression angebracht. Die Tiere wurden 1–12 Wochen nach der Operation getotet. Proben wurden rontgenologisch, histologisch und durch oxytetracyclin labelling untersucht.

Es wurde gefunden, dass die Kompression eine bessere Fixation mit sich fuhrte und dass dadurch bessere Resultate im Hinblick auf die Schnelligkeit und die Haufigkeit der Heilung erhalten wurden. Die Heilung begann im Schenkelhals und schritt durch innere Kallusbildung uber die Osteotomiestelle zum Femurkopf weiter fort. Andrerseits spielte die aussere Kallusbildung eine relativ grossere Rolle bei Fallen, bei denen die Knochenenden schlecht gegen einander fixiert worden waren.

Die Form des Schenkelkopfes blieb unverandert, so lange er noch nekrotisch war. Der allmahliche Kollaps des Kopfes begann 6–12 Wochen nach der Osteotomie als Resultat der Revaskularisierung und der Knochenresorption, die mit der Regeneration verbunden war. Der Kollaps war in der Kompressionsgruppe mehr ausgeprägt.

Die Schlussfolgerung ist, dass Kompressionsosteosynthese eines Bruches im spongiosen Knochengewebe die Heilung fordert, wenn eines der Knochenfragmente nekrotisch ist, in der spateren Phase der Hei-

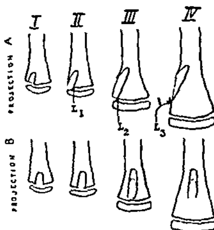


Figure 1 Picture published by A Langenskiold in 1957 Ollier's disease Schematic drawing of the development of a metaphyseal focus into a diaphyseal one with growth of the bone Stages I–IV in two projections perpendicular to one another

cording to several classical authors (*Ranvier Carey Policard*) a continuous supply of cells takes place at the periphery from the cartilage for the growth in length of the osteogenic layer of the diaphyseal periosteum The view that the epiphyseal plate grows in diameter by interstitial growth of the layer of the reserve cells and that the ossification groove (encoche d ossification) derives its cells from the cartilage tissue would be fully in accordance with the phenomenon illustrated in Figure 1

The question how the epiphyseal plate grows in diameter is still being discussed in recent literature (*Rigal Solomon*) Recent investigations concerning the fate of radioactive sulphate (^{35}S sulphate) bound to the ground substance of epiphyseal cartilage carried out by *Langenskiold Rytomaa & Videman* strongly support the view that the epiphyseal plate grows in diameter by interstitial expansion of the layer of the reserve cells

Dyschondroplasia is a rare disease and radiographs illustrating the development of the cartilaginous foci in this condition during skeletal growth are very seldom seen Figures 2–4 show radiographs of the hands of a child with dyschondroplasia It was possible to follow the development of typical longitudinal cartilaginous foci in the bones of the hands from the age of three years to the age of nine Figures 5 and 6 are contour drawings of the radiographs seen in Figures 2–4

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From the Orthopaedic Hospital of the Invalid Foundation, Helsinki, Finland
(Head: Professor A. Langenskiöld)

THE STAGES OF DEVELOPMENT OF THE CARTILAGINOUS FOCI IN DYSCHONDROPLASIA (OLLIER'S DISEASE)

By

A. LANGENSKIÖLD

Received 9.III.67

Radiographs of the extremities of a boy with Ollier's disease taken at intervals of two and a half years were published by the present author in 1947. The observations made in this case and a thorough study of the literature on the subject led to the conclusion that small and middle sized cartilaginous foci occurring in the long bones in dyschondroplasia develop in the manner shown schematically in Figure 1.

Ollier explained the histogenesis of the cartilaginous foci in the disease bearing his name in the following way: The disease is characterized by the irregularity and delay of ossification of the intermediary cartilages. The cartilage intended for the growth in length of the bones does not pass through the normal ossification process. It preserves its structure and persists in the form of more or less regular cartilaginous masses which often need a very long time for transformation into bone tissue. The correctness of this view has generally not been doubted by other authors. However, the phenomenon illustrated in Figure 1 is difficult to explain on the basis of the common conception that the epiphyseal plate normally grows in diameter by apposition of cells from a perichondrium at the periphery.

In 1949 *A. Langenskiöld & Edgren* reported results of experiments in which limited portions of epiphyseal plates in rabbits had been injured by heavy doses of roentgen rays. The experiments supported the view that in normal epiphyseal cartilage interstitial growth of the layer called the layer of the reserve cells causes an expansion of this layer and a successive displacement of its cells to the periphery in relation to the bony epiphysis and the cartilage cell columns. Ac-

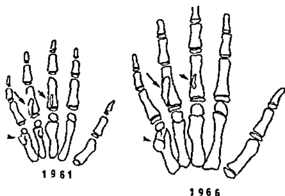


Figure 5 Contour drawings of the left hand as seen in Figure 2 and Figure 4 Arrows indicate three different foci as they appeared in 1961 and 1966

The radiographic findings in this case confirm the former observations illustrated schematically in Figure 1

In 1966 *Solomon* stated that serial radiographs of four patients with dyschondroplasia observed by him did not confirm the findings of the present author published in 1947 In the case illustrated by *Solomon* there was a large cartilaginous focus in the lower end of the femur and severe disturbance of growth It is obvious that the development of a metaphyseal focus into a diaphyseal one in dyschondroplasia can take place only when there are possibilities for the continued growth of the bone in question This means that the phenomenon oc

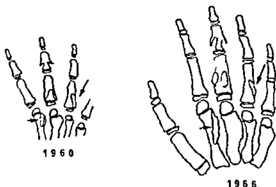


Figure 6 Contour drawings of the right hand as seen in Figure 2 and Figure 4 Arrows indicate two different foci as they appeared in 1960 and 1966 Compare with Figure 1



Figure 2 Radiograph of the left hand of a child with dyschondroplasia Age three years



Figure 3 Radiographs of the right hand of the child whose left hand is seen in Figure 2 Age three years





Figure 4 Radiograph of the same hands as seen in Figures 2 and 3 Age nine years

between normal and pathological cartilage in the epiphyseal plate In Figure 7 the arrow indicates such a limit between normal cartilage and chondroma tissue in the epiphyseal plate continuing into the metaphysis as a borderline between the tumor tissue and normal meta physeal bone

SUMMARY

The characteristic manner of development of cartilaginous foci in dyschondroplasia described by the author in 1947 (Figure 1) could be confirmed in a child with typical multiple cartilaginous foci in the hands Recent research concerning the fate of radioactive sulphate (^{35}S sulphate) in epiphyseal cartilage (*Langenskiöld Rytomaa & Videman)* has brougt new support to the author s conception of the patho genesis of dyschondroplasia

RESUME

La maniere caracteristique du développement de foyers cartilagineux dans la dyschondroplasie decrite par l auteur en 1947 (Figure 1) a ete confirmee chez un enfant des foyers cartilagineux multiples ty piques dans les mains Des recherches recentes concernant l accumula tion du sulfate radioactif (^{35}S sulfate) dans le cartilage epiphysaire (*Langenskiöld Rytomaa & Videman*) a apporte un nouveau point d ap pui a la conception de l autheur sur la pathogenèse de la dyschondro- plasie

ZUSAMMENFASSUNG

Die characteristische Entwicklung von den bei Dyschondroplasie auf tretenden Knorpelherden die vom Verfasser in 1947 (*Figure* 1) be schrieben wurde konnte bei einem Kind mit typischen multiplen Knorpelherden in den Handen bestatigt *werden* Neue Untersuchungen uber das Verhalten von radioaktivem Sulphat (^{35}S-Sulphat) im Epi physenknorpel (*Langenskiöld Rytomaa & Videman*) stutzen die Auf fassung des Verfassers von der Pathogenese der Krankheit

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Figure 7. Picture published by Speiser in 1925. The microphotograph shows a section of the peripheral part of the basis of the second phalanx of a big toe of a young child with enchondromatosis. The epiphyseal cartilage (Ep) is seen in the left lower corner. The periosteum (P) is seen to the right. The arrow indicates the limit between normal epiphyseal cartilage and a chondroma. This limit continues into the metaphysis as a borderline between enchondroma tissue and metaphyseal bone.

curs especially when a focus is small or of middle size. However, even the displacement of the base of a small focus from the epiphyseal plate to the surface of the bone is *difficult* to explain if it is assumed that the plate grows in diameter by apposition from the periphery.

In 1925 *Speiser* was able to carry out a thorough microscopic study of the entire skeleton of a child who died from anemia caused by enchondromatosis. Figure 7 shows one of *Speiser*'s illustrations in which a part of the epiphyseal plate of the second phalanx of a big toe and an enchondroma occupying the peripheral part of the plate is seen. In 1949 the present author stated that the "oblique lines" in the metaphyses in Ollier's disease are traces left behind by the limits

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POTT'S PARAPLEGIA TREATED BY ANTERO LATERAL DECOMPRESSION IN THE THORACIC AND LUMBAR SPINE

A Report of Twenty Seven Cases

By

A LANGENSKIÖLD & I B RISKA

Received 27 II 67

When effective drugs for the treatment of tuberculosis made radical and successful surgery for tuberculosis of the spine possible it seemed advisable that this active treatment should be centralized to hospitals in which special interest was taken in this field of surgery In the Orthopaedic Hospital of the Invalid Foundation radical operations for spinal tuberculosis were performed with good results starting in 1949 (*Bakalim & A Langenskiöld*) However the results of the treatment of Pott's paraplegia were poor until the book on this subject published by *Griffiths Seddon & Roaf* (1956) called attention to the possibility of antero lateral decompression of the spinal cord in this condition (*Alexander* 1946) The detailed description of the operation given in the book mentioned and the results reported encouraged us to follow the advice given by its authors

Since the first case of Pott's paraplegia was treated in our hospital by antero lateral decompression in February 1958 twenty seven patients have undergone this operation All operations have been performed by the same surgeon (A Langenskiöld) The results have confirmed the optimism of *Griffiths Seddon & Roaf* expressed in 1956

Not many series of cases treated by antero-lateral decompression have been published (*Hodgson et al Paus Vinh Silva Riska et al Ingelrans et al*) *Hodgson & Stock* who reported the second largest series had treated thirty five cases Single cases have been reported by *E Kallio Schulle* and *Weber Kirkaldy Willis et al* contributed to the technique of operation (1965 1966)

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Table 1 Duration of Skeletal Disease before the Appearance of Paraplegia

Skeletal disease present	Results of treatment of paraplegia			
	Complete recovery	Improved	No improvement	Death
1 to 5 months	3			
1 to 2 years	1	1	1	
3 to 7 years	2		3	
11 to 14 years	5		1	1
18 to 22 years	3	1		
30 to 45 years	5			
Total	19	2	5	1

Table 2 Age at Time of Surgical Intervention

Age (years)	No. of cases
15 – 20	5
21 – 30	6
31 – 40	7
41 – 50	5
51 – 60	1
61 – 70	3
Total	27

The degree and duration of motor paralysis are shown in Table 3 and the level and extension of spinal tuberculosis in Table 4. Only for a few of the first patients was a *plaster bed made before operation. Later the use of plaster beds in the treatment of tuberculosis* of the thoracic or lumbar spine was discarded.

Operation. The excellent description of the technique of antero-lateral decompression in Pott's paraplegia given by *Griffiths, Seddon & Roaf* in 1956 formed a firm basis on which the use of this procedure could be started *with success in the first case.* In the main, the technique described and the advise given by the authors have been followed in this series of cases.

In three cases decompression was carried out in the lumbar spine, in the other cases in the thoracic spine. The operative findings in the twenty-seven cases are shown in Table 5. As the onset of paraplegia had been late in most cases, it is not surprising that bony ridges or hard bony *sequestra* were the main compressing factor in twenty of them. The statement of *Griffiths, Seddon & Roaf* that the compressing agent will always be found at the region of the apex of the kyphosis was confirmed.

The distance that which the anterior aspect of the cord had to be decompressed varied. In one case eleven spinal roots had to be exposed, in one case six roots, in ten four roots, in seven three roots and in one case only two roots. In a few cases

For the treatment of fresh tuberculous foci in the spine in adults in 1960 we considered radical evacuation of the focus combined with interbody fusion at the same session the fastest way to recovery. However, having seen large progressive foci with abscesses heal within two to three months of drug treatment so that only scar tissue is found at operation, we tend to avoid unnecessary operations for tuberculosis of the spine. *Ingelrans & Lacheretz* had the same experience.

When paraplegia has occurred in Pott's disease the situation is different. The main purpose of operation is then the saving of the function of the spinal cord and not radical evacuation of the tuberculous focus. This is especially true when paraplegia occurs late in the disease. During the years when antero-lateral decompression has been practised at this hospital several old patients with Pott's paraplegia in an early stage of spinal tuberculosis have been treated conservatively with a complete cure.

MATERIAL

The most important data concerning the twenty-seven cases are given in Table 1.

History. In twenty-one of the patients paraplegia appeared more than three years after the onset of spinal tuberculosis. In three cases it appeared one to two years after the onset of spinal disease and three patients were paraplegic within five months after diagnosis of spondylitis (Table 1). Most of the patients were sent from other hospitals in the paraplegic state.

Preoperative condition and examination. Nineteen patients were males and eight females. Only four patients were operated on within two weeks of admission to the hospital, nine patients were operated on two to four weeks and nine patients four to eight weeks after admission. Five patients were operated on more than two months after admission. The timing of the operation depended on the estimated value of preoperative drug treatment and breathing exercises in relation to the danger of prolonged compression of the spinal cord in the individual case. The age distribution of the patients is shown in Table 1. The preoperative examinations included complete muscle testing of the trunk and the lower extremities, examination of the vital capacity of the lungs and of kidney function. Four of the patients had been treated earlier for urogenital tuberculosis. None of the patients had active tuberculosis of the lungs. All patients received full treatment with tuberculostatic drugs from admission to the day of operation.

The entire spine was radiographed and the kyphotic area was tomographed in two planes. Side view tomography proved especially valuable for planning of the operation. Myelography was considered contra-indicated and of no value in this group of cases.

In only one of seven patients in which no active tuberculosis was found at operation was the sedimentation rate of the blood slightly elevated before operation. On the other hand several patients had a normal sedimentation rate in spite of active spinal foci being present.

Table 1 Duration of Skeletal Disease before the Appearance of Paraplegia

Skeletal disease present	Results of treatment of paraplegia			
	Complete recovery	Improved	No improvement	Death
1 to 5 months	3			
1 to 2 years	1	1	1	
3 to 7 years	[illegible]		3	
11 to 14 years	5		1	1
18 to 2[illegible] years	1	1		
32 to 4[illegible] years	5			
Total	19	2	5	1

Table 2 Age at Time of Surgical Intervention

Age (years)	No. of cases
15 – 20	5
21 – 30	6
31 – 40	7
41 – 50	5
51 – 60	1
61 – 70	3
Total	27

The degree and duration of motor paralysis are shown in Table 3 and the level and extension of spinal tuberculosis in Table 4. Only for a few of the first patients was a plaster bed made before operation. Later the use of plaster beds in the *treatment of tuberculosis* of the thoracic or lumbar spine was discarded.

Operation. The excellent description of the technique of antero lateral decompression in Pott's paraplegia given by *Griffiths, Seddon & Roaf* in 1956 formed a firm basis on which the use of this procedure could be started with success in the first cases. In the main the technique described and the advice given by the authors mentioned have been followed in this series of cases.

In three cases decompression was carried out in the lumbar spine, in the other cases in the thoracic spine. The operative findings in the twenty seven cases are shown in Table 5. As the onset of paraplegia had been late in most cases it is not surprising that bony ridges or hard bony sequestra were the main compressing factors in twenty five of them. The statement of *Griffiths, Seddon & Roaf* that the compressing agent will always be found at the region of the apex of the kyphosis was confirmed.

The distance at which the anterior aspect of the cord had to be decompressed varied. In one case seven spinal roots had to be exposed, in one case six roots, in ten four roots, in seven three roots and in one case only two roots. In a few cases

Table 3 Results According to the Duration of Motor Paralysis

Severity and duration of motor paralysis	Complete recovery	Improved	No improvement	Death
Complete motor loss				
14 days – 1 month	8			
1 month – 4 months	2		1	
4 months – 7 months	1			
7 months – 1 year		1		
1 year – 2 years			1	
4 years – 7 years			3	
Incomplete motor loss				
3 months – 4 months	2			1
6 months – 8 months	4			
1 year – 2 years	1			
3 years	1			
14 years		1		
Total	19	2	5	1

Table 4 Level of Lesion in the Spine

Level	Complete recovery	Improved	No improvement	Death
Disease between				
T I and T X			1	1
T IX and T X			1	
T X and T XI	2			
T X and L I	4		1	
T XI and T XII	6	1	1	
T VIII and T XI	1	1	1	
T X and T XII	2			
T XI and L V	3			
T XII and L IV	1			
Total	19	2	5	1

the dura was covered by firm fibrous tissue which had to be peeled off to achieve decompression

When dealing with firm bony ridges compressing the cord from the anterior aspect in this series of cases it was found advantageous to remove the internal gibbus with a chisel leaving a shell of bone between the resulting cavity and the spinal cord This should be done when the pedicles separating the intervertebral

foramina have been removed and the anterior aspect of the dura has been located along the length necessary in the particular case When most of the internal gibbus has been removed the thin bony roof between the cavity and the spinal cord can be broken down into the cavity with minimal risk of additional damage to the cord

With some exceptions to be described below pulsation of the dura could be seen to have returned after decompression

In several cases one to three of the intercostal *nerves were so thin and atrophied* that they had to be sacrificed for the efficacy of the operative work

At the operation decompression of the cord was aimed at and not radical evacuation of tuberculous foci These were in many cases to wide spread to be dealt with radically (cf Figure 2)

In seven patients no active tuberculous focus was found at the operation Three of these patients (Nos 12 14 and 15) were cured by the antero lateral decompression It seems obvious that degeneration of intervertebral disks or stress on de

Table 5 Results Obtained According to Cause of Compression

Cause of compression	Complete recovery	Improved	No improvement	Death
Pus and granulation tissue	2			
Bony ridge or hard sequestra with pus and granulation tissue	6		2	
Bony ridge or hard sequestra with granulation tissue	8	1	1	
Bony ridge without granulation tissue	3	1	2	1
Total	19	2	5	1

Table 6 Age of Patients at the Antero Lateral Decompression Operation

Age (years)	Complete recovery	Improved	No improvement	Death
15 20	2		2	1
21 30	3	2	1	
31 40	6		1	
41 50	5			
51 60	1			
61 70	2		1	
Total	19	2	5	1

formed vertebrae may provoke compression of the cord in kyphotic spines after complete healing of the tuberculous process.

Complications at operation. Perfect service from the anaesthetists was available at and after all operations, which tended to reduce the frequency of complications. Bleeding during exposure of the ribs was reduced by injecting diluted solution of adrenaline into the tissues before incision. Rupture of intercostal arteries occurred frequently, but bleeding was always controlled by diathermy, fibrin foam and thrombin solution.

In four cases rupture of the dura occurred without serious consequences.

Rupture of the pleura occurred in three cases (Nos. 1, 5 and 21). In all of them a catheter was left in the pleural cavity and withdrawn after suction following closure of the wound. However, in one cases (No. 5) severe atelectasis of both lungs followed, resulting in death. This was one of the few patients who were not postoperatively treated in a special ward staffed by personnel trained in the after care of patients who have undergone thoracic surgery. Severe kyphosis, which was present in this case, creates a predisposition for atelectasis. *Griffiths, Seddon* & *Roaf* also considered rupture of the pleura a serious accident in this group of cases. If rupture of the pleura occurs in patients with excessive kyphosis, we recommend that continuous suction of the pleural cavity should be maintained for several days.

Postoperative care. It was found to be more advantageous to provide some mobility of the patient in a recumbent position than to immobilize him in a plaster bed immediately after operation. During the first few days the patients were positioned lying on the operated side to promote function of the contralateral lung.

The time of recumbency varied largely depending on the operative findings and the course of recovery. The shortest time from operation to walking was one month (No. 27), a patient who recovered rapidly from incomplete loss of motor function and who had a stable row of vertebral bodies.

It was generally felt that recumbency for more than three months would be more harmful than raising the patient in a tilting bed after this time.

When no tuberculous focus was found at operation, tuberculostatic drugs was not given postoperatively. In the other case drug treatment generally continued for two years.

Reoperation for failure to respond to antero-lateral decompression. In two cases re-exposure of the spinal cord was considered indicated. In one case (No. 7) the dura had been found to be thickened and firm at decompression and pulsation did not appear. As it was surrounded by pus, opening the dura was considered contra-indicated. When no return of motor function could be seen three months later, the spinal cord was re-exposed and the dura was opened longitudinally for a distance of about five centimeters and left open. Two weeks later motor function started to return but the recovery from paraplegia was *incomplete*.

In a woman aged 65 years no return of motor function was seen three months after adequate decompression of the cord (No. 22). The spinal cord was re-exposed three and a half months after the first operation. No compression was found and the dura was incised longitudinally and left open. Pulsation in the cord was seen. Motor function *did not return*.

Spinal fusion. Anterior spinal fusion was not attempted in any of the cases. In



Figure 1 A Case No 13 Side view radiograph of the kyphotic area before antero lateral decompression B Side view radiograph after decompression In this case posterior fusion was not considered necessary



Figure 2 A Case No 21 Sideview tomograph of the kyphotic area before antero lateral decompression B Side-view tomograph after decompression Internal gibbus radically removed leaving an unstable row of vertebral bodies Adequate posterior fusion had been carried out at an earlier stage

eleven cases posterior fusion was carried out two to four months after antero lateral decompression In one case posterior fusion was performed five months after decompression and in another seven months

In the cases which did not show signs of recovery from paraplegia after operation (Nos 9 10 17 19 and 26) spinal fusion was not considered indicated In two cases advanced age was considered a contra indication for prolonging the period

)perative find ngs	Number of roots exposed	Motor functi n began to return	Sensation began to return
: um granulation tissue	4	1 day after operation	1 month after operation
t ue b)ny ridge *discus sequestra*	4	9 days after operation	9 days after operation
ue b) y ridge	4	1 month after operation	9 months after operation
iti n tissue	3	2 weeks after operation	7 months after operation
	5	—	—
ti tissue	4	2 weeks after operation	2 months after operation
ue hard sequestra	5	10 months after operation	10 months after operation
n tissue bony ridge	7	9 days after operation	2 days after operation
	4	—	—
ue b ny ridge	5	—	—
n ti ue discus sequestra	3	1 da after operation	9 weeks after operation
	4	0 days after operation	Record n t exact
n t ue h rd eque tra	4	2 days after operation	Record not exact
	5	2 days after operation	2 months after operation
	4	45 days after operation	4 months after operation
ue b ny ri lge	3	1 day after operation	Record not exact
	5	Slight 10 months after o[illegible]	Slight 10 months after op
ue l r lge	5	6 days after operation	Within 2 months
e hard equestr bony ridge	5?	1 month after operation	3 months after operation
e d us seque tra bony ridge	4	2 weeks fter ope ation	1 month after operation
s e hard questra	3	1 day after operation	10 days after operation
on tis ue b ny ridg	3	—	—
n ti i di cu sequestra	2	4 months after operation	11 months after operation
is ue b)ny ridge	5	2 days after operation	1 month after operat on
n ti u hard seq estra l ony ridge	6	—	—
	3	2 days after operation	1 week after operation
u hard seque tr bony ridge	3	1 day after operation	1 day after operation

Spinal fusion	Result of operation for paraplegia (Time within which results reached)	Follow up time
June 4 19 8	Complete recovery 1 year 2 months	7 years 9 months
Oct 8 1958	Complete recovery 9 months	8 years 3 months
Aug 28 1959	Complete recovery 1 year 3 months	6 years 6 months
Jan 25 1960	Complete recovery 1 year 1 month	7 years 6 months
—	Dead oct 28 1959	—
July 12 1960	Complete recovery 8 months	4 years
Febr 27 1962	Improved 2 years	2 years 5 months
Aug 16 1960	Complete recovery 7 months	6 years 9 months
—	No improvement	3 years 11 months
—	No improvement	7 years 11 months
—	Complete recovery 1 year	1 year Dead from other disease
Nov 3 1961	Complete recovery 5 months	5 years 6 months
Aug 7 1961	Complete recovery 4 months	5 years 1 month
—	Complete recovery 7 months	[illegible] years 6 months
—	Complete recovery 1 year	5 years 3 months
March 23 1962	Complete recovery 9 months	[illegible] years 2 months
—	No improvement	4 years 2 months
July 2 1962	Complete recovery 5 months	4 years 9 months
—	Complete recovery 8 months	4 years 5 months
Oct 15 1962	Complete recovery 1 year 4 months	3 years 9 months
1947 dec 11 1951	Complete recovery 2 months	2 years 10 months
—	No improvement	2 years 1 month
—	Complete recovery 1 year	1 year 3 months
Aug 18 1964	Complete recovery 1 year	2 years 9 months
Febr 2 1965	No improvement	2 years 3 months
—	Improved 4 months	1 year 1 month
—	Complete recovery 2 months	9 months

e and level of ensory loss	Level of spinal lesion	Date of decompression *operation*	Age at operation (years)	
red bel w Th X	Th XI XII	Febr 3 1958	44	Pus hard
red below Th X	Th IX I II	July 7 1958	49	Pus gran
ired bel w I IV	Th XI L V	April 9 1959	48	Granulati
ired below Th VIII	Th VI–X	Aug 20 1959	32	Pus and
ly impa rment	Th I–X	Oct 27 1959	14	*Bony ridg*
olete loss below Th VII	Th VI VIII	March 17 1960	16	Pus and g
aired b low Th X	Th VIII XII	March 31 July 11 1960	28	Granulati
aired bel w Th X	Th VII XII	*May 2 1960*	*31*	*Pus gran*
aired below Th X	Th V–IX	July 6 1960	16	Bony ridg
aired bel w I I	Th VII XII	July 6 1960	17	Granulati
aired below Th X	Th VIII–XI	*Aug 22 1960*	63	Pus gran
ht impairment bel w Th X	Th VII L I	Aug 2 1961	2	Bony ridg
ht impa ment below Th XI	Th VIII L I	Jan 3 1962	28	Pus granu
paired below Th X	Th VIII L III	*Aug 9 1961*	37	Bony ridg
tel y mpa rment	Th VII XII	Nov 6 1961	38	Bony ridg
tchy imp ment	Th X XII	Dec 18 1961	52	Granulati
mpl te l bel w Th VII	Th II XI	*April 18 1962*	39	Bony ridg
ipaired bel w I II	Th XII L IV	Aug 1 1962	27	Granulati
ight impai m nt bel w I I	Th VII I IV	Aug 16 1962	45	Granulati
ight mp i m nt b l w Th X	Th V VI	May 1962	34	Granulati
atchy imp ment	Th VII L I	Jan 20 1964	41	Granulati
omplete l bel w Th VIII	Th VIII IX	Febr 12 June 4 1964	6	Pus gran
mpai ed bel Th X	Th V–XI	*May 6 1964*	64	Pus gran
mpaired below Th VIII	Th VII X	May 11 1964	15	Granulati
mpair d	Th IX X	Sept 24 1964	24	Pus gran
Impaired bel w Th X	Th IX XI	*Jan 19 1966*	30	Bony ridg
Patchy impai m nt	Th X I I	March 16 1966	*39*	Granulat

Table 7

Case number	Sex	Age when tub. of spine occurred (years)	Age when paraplegia occurred (years)	Degree and duration of motor paralysis before operation
1	♀	26	40	Complete loss 1 month slight spasms
2	♂	30	49	Complete loss 1 month slight spasms
3	♂	3	48	Complete loss 3 months slight spasms
4	♀	32	32	Complete loss 4 months severe spasm
5	♂	2	14	Complete loss 4 months slight spasms
6	♂	10	15	Complete loss 4 months severe spasm
7	♀	5	27	Complete loss 7 months slight spasms
8	♂	3	31	Complete loss 2 weeks severe spasm
9	♂	2	4	Complete loss 4 years severe spasms
10	♂	3	9	Complete loss 7 years severe spasms
11	♀	60	63	Complete loss 1 month flaccid
12	♂	10	21	Complete loss 1 month slight spasms
13	♂	16	27	Incomplete loss 8 months severe spasms
14	♀	3	37	Complete loss 3 months slight spasms
15	♂	5	37	Incomplete loss 1 year 2 months severe s
16	♂	18	52	Complete loss 1 month severe spasms
17	♀	3	9	Complete loss 1 year severe spasms
18	♂	3	24	Incomplete loss 3 years slight spasms
19	♂	3	44	Incomplete loss 6 months severe spasms
20	♂	33	34	Incomplete loss 7 months severe spasms
21	♂	25	36	Incomplete loss 4 months slight spasms
22	♀	57	64	Complete loss 45 days severe spasms
23	♂	64	64	Complete loss 1 month slight spasms
24	♂	4	15	Complete loss 1 month severe spasms
25	♀	2	14	Complete loss 7 years severe spasms
26	♂	15	16	Incomplete loss 14 years severe spasms
27	♂	20	38	Incomplete loss 8 months

of recumbency by a fusion operation (Nos 11 and 23) In two cases spinal fusion had been carried out before paraplegia indicated antero lateral decompression (Nos 13 and 21) and in four cases the row of vertebral bodies was considered stable enough to render posterior fusion unnecessary (Nos 14 15 18 and 27 cf Figure 1)

After posterior fusion performed by implanting tibial or iliac bone grafts on the laminae on both sides of the spinous processes the patients were recumbent for about two months

RESULTS

The results of antero lateral decompression in the present series of cases are shown in the Tables 1 and 3–7 In nineteen patients the motor function and the sensation of the lower extremities returned to normal with normal reflexes and a negative Babinski test One patient (No 5) who might have had a good chance of recovery from adequate decompression died on the fifth postoperative day from complications due to rupture of the pleura at operation Autopsy showed extensive atelectasis of both lungs to have been the cause of death

In two patients function clearly improved as a result of the operation (Nos 7 and 26) In five patients no improvement was seen after decompression Two of these (Nos 9 and 10) were young boys who had been completely paraplegic for more than eight years Seeing other patients recover from a similar condition they wanted to take the chance of improvement by operation although it seemed very slight Both are now working in wheelchairs as television technicians In one patient aged 65 years (No 22) reoperation showed that decompression had been adequate

In one patient with paraplegia of long standing operation had been refused one year earlier because chances of recovery were considered non existent However pain and continuous elevation of the sedimentation rate of the blood in spite of drug treatment indicated *operation* The internal gibbus with an active tuberculous focus was removed The sedimentation rate dropped to normal and the general condition of the patient improved although paraplegia remained (No 25)

In one patient slowly progressing paraplegia from a bony ridge without active tuberculosis did not respond to operation in spite of adequate decompression of the spinal cord (No 17)

Considering the primarily bad prognosis in four of the five unsuccessful cases the results obtained by antero lateral decompression in this series support the enthusiasm of *Griffiths Seddon & Roaf* as to the value of this operation as a treatment for Pott s paraplegia

SUMMARY AND CONCLUSIONS

Twenty-seven cases in which antero-lateral decompression of the spinal cord was carried out for Pott's paraplegia are reported.

Nineteen patients recovered, attaining full function of the lower extremities. One patient died from atelectasis of both lungs following rupture of the pleura at operation. In two patients mobility was im*proved by operation*, and in five cases the paraplegic condition remained unchanged. In two of these five, paraplegia of many years' duration rendered recovery from operation improbable, and in two cases slow progression of paraplegia over a number of years motivated a guarded prognosis. In one case reoperation revealed adequate decompression but no function returned.

Antero-lateral decompression is considered the treatment of choice for paraplegia of late onset in Pott's disease. The prognosis seems to be favourable when the operation is radically and carefully carried out before complete motor loss of the lower extremities has been present for more than seven months. Incomplete motor loss may be cured even years after onset of paresis.

When removing a bony ridge compressing the spinal cord from the *anterior aspect, it has been found advantageous to remove the internal* gibbus first, leaving a shell of bone between the resulting cavity and the dura. The last step of decompression can then be carried out by breaking this thin shell down into the cavity with minimal risk of operative damage to the cord.

RÉSUMÉ

Il est rapporté vingt-sept cas dans lesquels une décompression antéro-latérale du cordon médullaire a été pratiquée pour remédier à une paraplégie du Mal de Pott.

Dix-neuf malades furent guéris et retrouvèrent l'entière fonction des *extrémités inférieures. Un malade est décédé* d'atélectasie des deux poumons due à une rupture de la plèvre pendant l'opération. Chez deux malades la mobilité a été améliorée par l'opération et dans cinq cas l'état paraplégique est resté inchangé. Chez deux des *cinq* une paraplégie qui durait depuis plusieurs années rendait improbable une guérison par l'opération et dans deux cas une lente progression de la paraplégie à travers un certain nombre d'années motiva un pronostic prudent. Dans un cas une nouvelle opération montra que la décom*pression* voulue se produisait bien mais sans qu'il intervînt un retour de la fonction.

La décompression antero latérale est considérée comme le traitement de choix de la paraplegie dans les attaques tardives du Mal de Pott. Le pronostic semble etre favorable lorsque l'opération est radicale et minutieusement executée avant qu'une perte complète de la force motrice des extremités inferieures ait duré plus de sept mois. Une perte incomplete de la force motrice peut etre querie meme plusieurs années apres une attaque de paresie.

Lorsqu'il est enlevé un pont osseux comprimant le cordon médullaire du coté anterieur, il est avantageux d'enlever la gibbosité interne en laissant d'abord une ecaille osseuse entre le cavité qui se produit et la dure mere. Le dernier stade de la decompression peut etre pratiqué en brisant cette mince ecaille dans la cavité avec un risque minime de dommages operatoires du cordon medullaire.

ZUSAMMENFASSUNG

Siebenundzwanzig Fälle, in denen eine antero laterale Dekompression des Ruckenmarks wegen Paraplegie bei Wirbeltuberkulose ausgeführt wurde, werden beschrieben.

Neunzehn Patienten genasen vollständig und bekamen eine vollständige Funktion der unteren Extremitäten wieder. Ein Patient starb von Atelektase beider Lungen nach Ruptur der Pleura bei der Operation. Bei zwei Patienten wurde die Beweglichkeit von der Operation gebessert und in fünf Fällen blieb der Zustand unverändert. In zwei von diesen fünf war eine Genesung nach mehrjährigen Paraplegie unwahrscheinlich und in zwei Fällen machte eine langsame Progredienz der Paraplegie während mehreren Jahren die Prognose unsicher. In einem Fall zeigte eine Reoperation, dass die Dekompression nach der ersten Operation vollständig war, aber eine Besserung der Funktion der Gliedmassen trat nicht ein.

Die antero-laterale Dekompression ist die Methode der Wahl bei der Behandlung einer Paraplegie, die spät im Verlauf der Wirbeltuberkulose auftritt. Die Prognose scheint günstig zu sein, wenn die Operation radikal und mit Vorsicht ausgeführt wird, vor eine vollständige Lahmung der unteren Gliedmassen mehr als sieben Monate vorhanden gewesen ist. Eine unvollständige Lähmung kann auch nach jahrelangem Bestehen behoben werden.

Bei der Entfernung einer knochernen Kante, die das Ruckenmark von der Vorderseite komprimiert, hat man es vorteilhaft gefunden den inneren Callus zuerst mit dem Zurucklassen einer dünnen Knochen

schicht zwischen der entstehenden Kavität und dem Ruckenmark auszufuhren Der letzte Schritt der Dekompression ist dann durch das Brechen der dunnen Knochenschicht in die Kavität hinein mit einem minimalen Risiko fur eine Schädigung des Ruckenmarks durchgefuhrt

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FRACTURES OF THE FIRST RIB

Report of Two Cases of Bilateral Fracture of First Rib

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Fractures of the first rib are rare. Only about 270 cases are known in the literature and only 22 of these were bilateral. Still, the majority of these cases were found incidentally during routine chest radiographs in young men without any history of relevant trauma. This fact gave rise to skepticism whether this was a developmental anomaly rather than a true fracture (*Bowie & Jacobson* 1945, *Sycamor* 1944, *Gershon Cohen & Delbridge* 1945). However, few cases have been reported in which fracture followed lifting, straining or collison and gave rise to symptoms. Furthermore in a few cases an earlier radiograph was available showing a previously intact rib (*Alderson* 1947, *Jenkins* 1952), a fact which establishes beyond any doubt the traumatic character of these particular lesions.

There have been several explanations as to the etiology and the mechanism of the fracture of the first rib.

The anatomical features and relations of the first rib protect it, however, from direct external violence, make it susceptible to indirect violence, stress and sudden muscular contractions. The first rib is broad and flat with a groove for the subclavian artery on its upper surface which weakens the middle part of the bone. On either side of the groove the scalene muscles are inserted exerting a constant upward tension on that part of the rib. The anterior part of the rib is immovably fixed to the manubrium through the first costal cartilage. The attachment of the first digitation of the serratus anterior, the subclavian muscle and the costoclavicular ligament render the anterior half of the first rib even less mobile. Sudden and violent contraction of the scalene muscles cause a bending strain at the thinnest and more mobile seg-

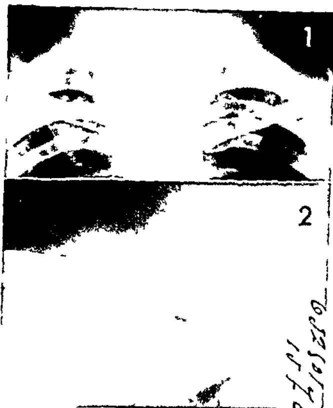


Figure 1 Transverse fracture of both first ribs caused by sudden muscular contraction. Fractures caused by this mechanism are constantly located in the region of the groove for the subclavian vessels (Case 1).

Figure 2 (Case 1) X Ray of the right shoulder taken three months before the accident shows clearly that there was not any preexisting defect in the first rib.

ment of the rib and may fracture it (*Allen & Lincoln* 1939). Isolated fractures of the first rib are seldom produced by direct external violence although in the first record of such a fracture the mechanism of injury was direct violence by repeated kicks (*Jones* 1869). Fractures of the first rib due to direct external violence are most often associated with fractures of the protecting shoulder girdle or of other ribs and may be complicated by injury to the pleura causing haemothorax or pneumothorax. There may be too an associated injury of the subclavian vessels.

A third mechanism by which the first rib may fracture is indirect violence. *Powell* (1950) described three cases of fracture of the first rib caused by this mechanism. One of his patients suffered a shoulder to shoulder collision with another footballer, another fell on to his outstretched hand, and a third suffered a forcible hyperabduction at the shoulder.

Finally, there are cases in which a fracture of the first rib is unassociated either with muscular contraction or with any form of violence; it does not produce symptoms and it is discovered incidentally. It may be assumed that in these cases it is a stress or fatigue fracture (*Proctor et al.* 1945).



Figure 3 Same as Figure 1 Five months later there is a callus formation but not certain union

Figure 4 Same as Figure 1 and 3 At fifteen months there is sound union of the fracture of both first ribs

CASE REPORTS

Case I A healthy young painter aged twenty eight was working on a scaffolding facing a wall when suddenly the board on which he was standing cracked Instantly he grasped a bar above pulling at the same time his head back forcibly in order to avoid striking his face on the wall At this moment he experienced acute pain behind the clavicle which persisted afterwards radiating in to the shoulder scapulae and upper chest and having a stabbing character The pain was aggravated on deep breathing or coughing Abduction or flexion of the arms increased the pain

On clinical examination the day after the accident the pain was situated behind the clavicle Any active movement of the shoulders produced acute pain There was tenderness in the neck triangle in both sides

X R showed transverse fractures of both first ribs in the region of the groove (Figure 1)

Because of the severity of the symptoms a figure of eight bandage was applied to restrict the shoulder movement This proved sufficient to relieve acute pain Immobilisation of the shoulders in this way continued for two weeks By then the patient complained only of discomfort By the end of the third week he was able

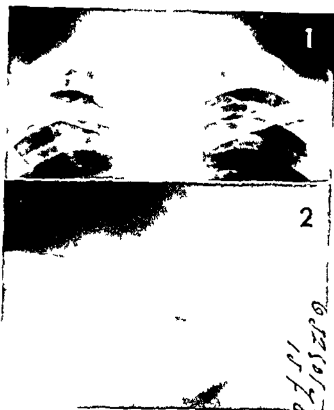


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ture of the left rib is double (Figure 5) After proper treatment the patient made an astonishing recovery and was discharged 13 days after the accident

Radiographs taken three and a half months after the accident show that both fractures of the left first rib have united The fracture of the right first rib which was displaced has not united, although an established pseudarthrosis (Figure 6) has not developed

Although the patient has not yet returned to work his only complaint is discomfort on lifting weights

SUMMARY

1 Two cases of bilateral fracture of first rib produced by different mechanisms are described

2 In the first case the existence of a radiograph which shows a previously intact rib proves that this was in fact a case of true spontaneous fracture due to sudden and forcible contraction of scalene muscles

3 In cases of direct violence as in our 2nd case fractures of the first rib are associated with fractures of other ribs and complicated by pleural injury

4 In the first case it took more than five months for fractures to unite In the second case the undisplaced double fracture of the one rib united in less than three and a half months The situation of the fracture may play a part in the rate of union

RESUME

1 Deux cas de fracture bilaterale de la premiere cote produite par differents mecanismes sont decrits

2 Dans le premier cas l existence d une radiographie qui montre une cote anterieurement intacte prouve qu il s agit en *realite d un cas* de fracture spontanee due a une contraction soudaine et forcee des muscles scalenes

3 Dans le cas de violence directe comme dans *notre 2eme cas les* fractures de la premiere cote sont associées aux fractures des autres cotes et compliquees de lesion pleurale

4 Dans le premier cas il s ecoula plus de *cinq mois* avant la soudure de la fracture Dans le second cas la double fracture sans deplacement d une seule cote se souda en moins de *trois* mois et demi La localisation de la fracture peut jouer un role pour le temps qui s écoule avant la soudure

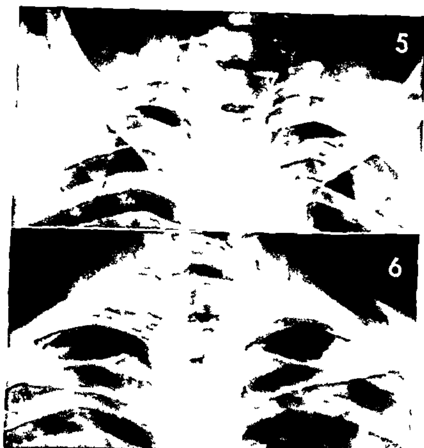


Figure 5 (Case 2) Fracture of both first ribs double on the left caused by direct violence The location of these fractures varies

Figure 6 Same as Figure 5 Three and a half months later the double fracture of the left first rib is united and the right one shows signs of union

to resume work although a slight discomfort remained for another week after which the patient was completely symptom free

Because of a trivial injury of his right shoulder three months before the recent accident the patient had an X Ray taken in which the right first rib is seen intact (Figure 2) This is certainly an undisputable proof that the lesion of the rib seen in the radiograph of the day of the accident is a recent fracture Five month after the accident X Rays shows hypertrophic callus but bony union is questionable (Figure 3) Final radiographs taken fifteen months after the accident show union of both first rib fractures (Figure 4)

Case 2 A young lorry driver aged 2 suffered a severe chest injury when he was squeezed under his overturned car On admission there was subcutaneous emphysema and a left pneumothorax but no paradoxical movement Radiographic examination showed fractures of both first ribs associated with fracture of clavicle and 2nd rib on the left and fracture of the 2nd 3rd 4th and th rib on the right The frac

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From the Orthopaedic Hospital of the Invalid Foundation Helsinki Finland
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EPIPHYSEODESIS OF THE GREATER TROCHANTER

By

A LANGENSKIOLD & P SALENIUS

Received 24 iii 67

In 1957 one of the present writers (*A Langenskiold*) introduced epiphyseodesis of the greater trochanter as a method of treatment for cases of moderate infantile coxa vara The idea of using epiphyseodesis of the greater trochanter as a measure of treatment arose from the observation of growth disturbances of the upper end of the femur encountered in the treatment of congenital dislocation of the hip (CDH)

Figure 1 A shows the hip of a child after closed reduction of congenital dislocation The shape of the upper end of the femur appears normal in the radiograph Ten years after reduction a radiograph of the same hip (Figure 1 B) showed that the growth from the epiphyseal plate of the femoral head had been disturbed and there was considerable hypertrophy of the greater trochanter The Trendelenburg test was negative Epiphyseodesis of the greater trochanter was planned but was not carried out Three years later (Figure 1 C) the hypertrophy of the greater trochanter was still more pronounced The Trendelenburg test was positive and a considerable limp had developed

Figure 2 shows a hip in which extreme hypertrophy of the greater trochanter caused by growth disturbance of the capital epiphyseal plate had developed after open reduction of CDH

Figure 3 A shows an unsatisfactory position of the left hip after closed reduction of CDH The shape of the upper end of the femur appears normal At open reduction of this hip the epiphyseal plate of the greater trochanter was damaged and extreme coxa valga developed (Figures 3 B and C)

Figure 4 shows a case of CDH in which open reduction of the right hip led to growth disturbance of the capital epiphyseal plate and coxa vara whereas the open reduction of the left hip resulted in a growth disturbance of the epiphyseal plate of the greater trochanter and coxa valga

ZUSAMMENFASSUNG

1. Zwei Fälle von doppelseitigen Brüchen der ersten Rippe, die durch verschiedenartigen Mechanismus entstanden waren, werden beschrieben.

2. Im ersten Falle zeigte eine frühere Röntgenaufnahme eine völlig intakte Rippe, wonach sich dieser Fall als ein spontaner Knochenbruch erweist, der durch eine plötzliche und starke Kontraktion des Scalenus muskels verursacht war.

3. Bei Rippenbrüchen nach direkter Gewalt, wie in unserem zweiten Fall, ist ein Bruch der ersten Rippen oftmals mit Brüchen weiterer Rippen sowie mit einer Beschädigung der Pleura verbunden.

4. Im ersten Falle dauerte die Frakturheilung mehr als fünf Monate. Im zweiten Falle wurde der doppelte, nicht verschobene Bruch der einen von den ersten Rippen in weniger als 3½ Monaten geheilt. Die Lokalisation eines Bruches dürfte die Schnelligkeit der Heilung eine gewisse Rolle spielen.

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Figure 2. Congenital dislocation of the left hip in a girl treated by open reduction at the age of two years. A. Age seven years. Short neck. Flattened head. Overgrowth of the greater trochanter. Trendelenburg sign negative. B. Age fifteen years. Extreme hypertrophy of the greater trochanter. Trendelenburg sign positive.

the length of the limb. A consequence of this experience was the idea that the disturbance of abductor function which threatens when growth is disturbed in the capital epiphyseal plate could be prevented by epiphyseodesis of the greater trochanter.

The fact that a disturbance of growth in the epiphyseal plate of the greater trochanter results in coxa valga, whereas a disturbance in the growth of the capital epiphyseal plate of the femur leads to coxa vara, was first pointed out by *Compere, Garrison & Fahey* in 1940. However the possibility of using epiphyseodesis of the greater trochanter as a therapeutic measure seems not to have been recognized before work on this problem was started in the Orthopaedic Hospital of the Invalid Foundation in 1947.

In 1950 *Laurent* confirmed the findings of *Compere et al.* using rabbits for his experiments. Destruction of the epiphyseal plate of the



Figure 1. Congenital dislocation of the right hip in a girl. A. The hip after closed reduction on June 11, 1939 at the age of one year. Normal shape of the upper end of the femur. B. Radiograph of the hip at the age of ten and a half years. Overgrowth of the greater trochanter. Shortening of the neck and flattening of the head of the femur. C. Age fourteen years. Considerable hypertrophy of the trochanter. Disabling limp. Two and a half centimeters shortening of the limb.





In Calvé-Legg-Perthes disease (coxa plana) a disturbance of epiphyseal growth in the head of the femur may lead to considerable overgrowth of the greater trochanter accompanied by insufficiency of the abductors of the hip and a marked limp. An example of such a course in coxa plana is seen in Figure 5.

The experience gained from a number of cases similar to those illustrated in Figures 1–4 showed that a severe disturbance in the growth of the capital epiphyseal plate of the femur led to gradual overgrowth of the greater trochanter ultimately resulting in a limping gait. On the other hand, a disturbance in the growth of the greater trochanter generally caused no disturbance in the function and no reduction of



48 mm

4B

Figure 4. Bilateral congenital dislocation of the hip in a girl. A. The hips at the age of two and a half years before open reduction. B. Age eight years. In the right hip open reduction was followed by growth disturbance of the capital epiphyseal plate resulting in coxa vara. In the left hip damage to the epiphyseal plate of the greater trochanter caused marked coxa valga. Trendelenburg sign positive on the right side and negative on the left.

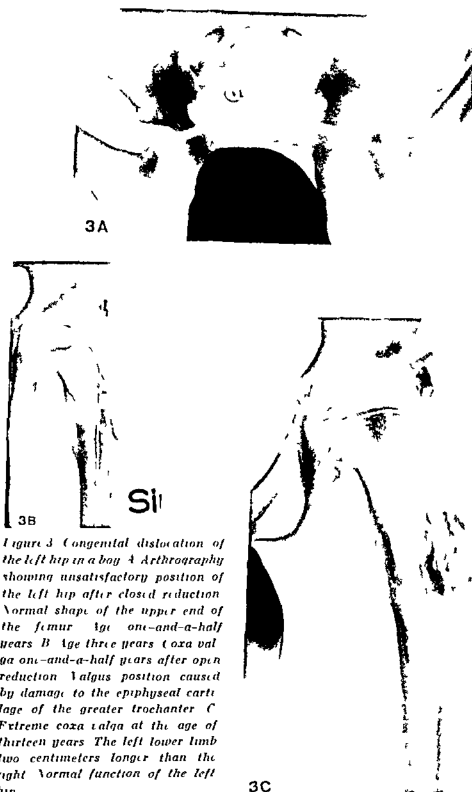


Figure 3 Congenital dislocation of the left hip in a boy A Arthrography showing unsatisfactory position of the left hip after closed reduction Normal shape of the upper end of the femur Age one-and-a-half years B Age three years Coxa valga one-and-a-half years after open reduction Valgus position caused by damage to the epiphyseal cartilage of the greater trochanter C Extreme coxa valga at the age of thirteen years The left lower limb two centimeters longer than the right Normal function of the left hip



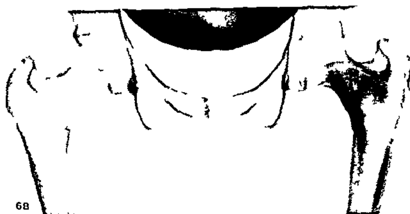


Figure 6 Infantile coxa [illegible] a of the left hip in a girl A Age nine and a half years Kept under observation from the age of seven Trendelenburg sign positive on the left side B Age fifteen years Epiphyseodesis of the left greater trochanter had been performed at the age of ten years and five months Trendelenburg sign negative The left lower limb was one centimeter shorter than the right Function of the left hip normal

be dealt with during the entire period of growth In addition cases of CDH treated without traction before reduction in other hospitals were often sent for further treatment to the Orthopaedic Hospital of the Invalid Foundation This is the background to the large number of cases of CDH in which epiphyseodesis of the greater trochanter has been carried out and which are reported below

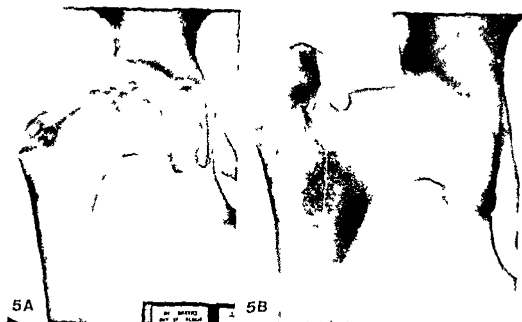


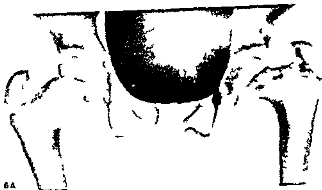
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greater trochanter in the rabbits produced a coxa valga deformity very similar to that seen in Figures 3 and 4 in this article.

In 1960, in his thesis on coxa vara infantum, *Pylkkänen* reported the first three cases in which epiphyseodesis of the greater trochanter was carried out for a moderate form of this disorder.

Although epiphyseodesis of the greater trochanter was introduced as a treatment for moderate infantile coxa vara, it was soon found that there was a large group of cases of coxa plana and of treated cases of CDH in which the operation seemed to be indicated as a prophylactic measure to prevent increasing limp from gradual overgrowth of the greater trochanter.

In 1957 the principle of using traction treatment before closed or open reduction on every child with CDH except the newborn was introduced in the Orthopaedic Hospital of the Invalid Foundation (*Langenskiöld & Laurent*). Growth disturbance of the capital epiphysis has seldom been seen in patients with CDH treated in this hospital since the year mentioned. However, the patients treated in an earlier period having severe growth disturbances in their hips (Figures 1–4) had to



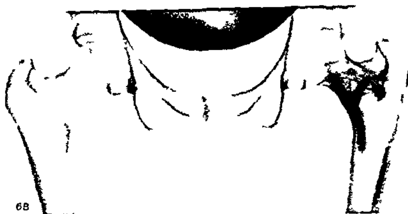


Fig. 6. Infantile coxa vara of the left hip in a girl. A: Age nine and a half years. Kept under observation from the age of seven. Trendelenburg sign positive on the left side. B: Age fifteen years. Epiphyseodesis of the left greater trochanter had been performed at the age of ten years and five months. Trendelenburg sign negative. The left lower limb was one centimetre shorter than the right. Function of the left hip normal.

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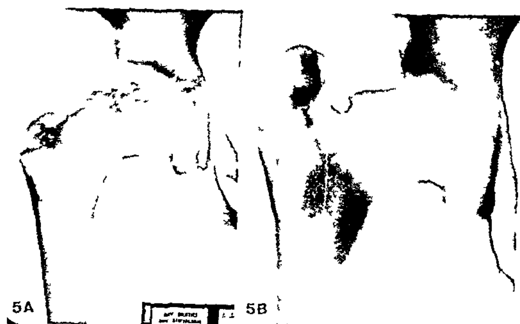


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8A


8B


8C


8D

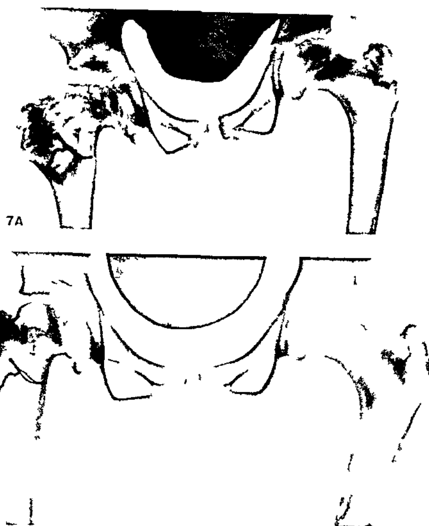
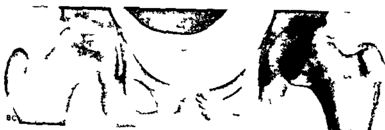


Figure 7. Bilateral infantile coxa vara. A. On the right side osteotomy of the femur had been performed for severe coxa vara. On the left side epiphyseodesis of the greater trochanter had been carried out two years before the radiograph was taken. Age twelve years and ten months. B. Age sixteen years. On the right side slight recurrence of coxa vara as a result of overgrowth of the greater trochanter. On the left side normal shape of the upper end of the femur after epiphyseodesis of the greater trochanter had been performed at the age of ten years.

Figure 8. Coxa plana on the left side in a girl. A. Age seven years and eight months. Growth disturbance of the left femoral head and neck. B. Age eleven years. Short neck and flattened head of the femur. Hypertrophy of the greater trochanter threatening. C. Age eleven and a half years. Radiograph taken four months after epiphyseodesis of the greater trochanter. D. Age twelve years and eight months. Normal function of the left hip. Compare with Figure 5.


8A


8B


8C


8D







Figure 9. Congenital dislocation of the left hip in a girl. A. Age six years and eight months. Radiograph taken before capsular arthroplasty a.m. Colonna. B. Age ten years. Growth disturbance of the femoral head and neck. Overgrowth of the greater trochanter threatening. C. Age fifteen years. Epiphyseodesis of the greater trochanter performed at the age of eleven years and nine months. Shortening of the limb by two centimeters. Slight limp. (f. Figure ?)

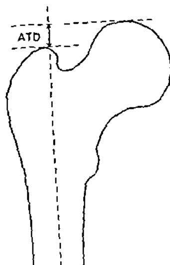


Figure 10 Determination of the articulotrochanteric distance (ATD) Edgren 1960 See the text given below

THE ARTICULOTROCHANTERIC DISTANCE (ATD)

In a monograph on coxa plana published in 1960 *Edgren* reported twenty five cases in which epiphyseodesis of the greater trochanter had been carried out for this disorder

For the estimation of the degree of abnormal position of the greater trochanter in relation to the head of the femur there was a need for a method of measurement For this purpose *Edgren* defined the concept of the articulo trochanteric distance (ATD) The manner of determination of the ATD from a radiograph is seen in Figure 10 The ATD is the difference in the level on the longitudinal axis of the femur of the tip of the bony part of the greater trochanter and the top of the head of the femur When the top of the head of the femur is on a more cranial level than the tip of the greater trochanter the ATD is considered positive and when the tip of the trochanter lies more cranial the ATD is considered negative

In order to ascertain the extent to which ATD is influenced by different rotational positions of the femur *Edgren* carried out radiological investigations on normal individuals and on a specimen With the standard technique of taking radiographs of hips in the hospital the error of measuring the ATD from radiographs is considered to be within ten per cent (*Edgren* personal communication)







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the indication was disturbance in the growth of the capital epiphyseal plate after closed or open reduction of congenital dislocation of the hip (CDH)

The estimation of the beneficial effect of epiphyseodesis of the greater trochanter in preventing insufficiency of the abductors of the hip in the individual case is made difficult by several factors The degree and the course of the growth disturbance of the capital epiphyseal plate which is decisive for the degree of threatening overgrowth of the trochanter cannot be estimated by radiography with any certainty Owing to the manner of growth of the trochanter a disadvantageous course of reduction of the ATD in a case with a severe disturbance of growth in the capital epiphyseal plate is reduced but not completely stopped by the epiphyseodesis Proof of the effect of the operation in a group of cases can thus be established by proving a definite change in the course of the reduction of the ATD after the operation

Only the group of cases of CDH in which epiphyseodesis of the greater trochanter was performed was found to be both large and uniform enough to permit statistical evaluation of the degree of the effect of the operation

Data concerning the cases of infantile coxa vara in which epiphyseodesis of the greater trochanter was performed are given in Table 1 Figures 6 and 7 show radiographs of two of these cases The disturbance in the growth of the head and neck of the femur varies very much in cases of moderate infantile coxa vara This makes the estimation of the effect achieved by epiphyseodesis of the trochanter unreliable However when progression of varus threatens the operation is indicated in this group of cases as an alternative to osteotomy

Data concerning the cases of coxa plana in which the operation had been carried out are shown in Table 1 Figure 8 shows radiographs of one of these cases Serial radiographs of this case had shown gradual reduction of the ATD in the affected left hip before epiphyseodesis of the greater trochanter was carried out at the age of eleven years At the age of twelve years the ATD was still + 4 millimeters The development of a condition similar to that seen in Figure 5 B was prevented by the operation

EPIPHYSEODESIS OF THE GREATER TROCHANTER INDICATED BY GROWTH DISTURBANCE IN THE CAPITAL EPIPHYSEAL PLATE AFTER TREATMENT FOR CDH

Some general data concerning the cases of CDH in which epiphyseodesis of the greater trochanter was carried out are given Table 1 In this group an attempt was made to evaluate statistically some of the data connected with the degree of overgrowth of the trochanter and the effect of the operation

It is known that the capital epiphyseal plate contributes about 30 per cent of the growth in length of the femur Although operations carried out for reduction of CDH particularly derotation osteotomy of the femur stimulate growth in the distal end of the femur discrepancy of leg length in unilateral cases of CDH can be expected to depend on the

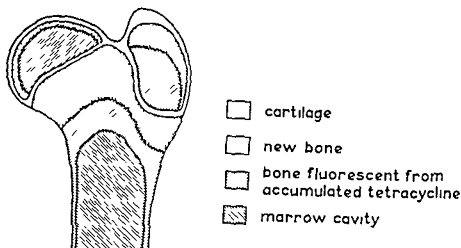


Figure 11. Drawing of a frontal section through the upper end of the femur of a fourteen-week-old pig injected eight weeks previously with tetracycline (Salenius).

In man the ATD of a normal hip is always positive in all age groups. In the series of cases of coxa plana reported by *Edgren* it could be clearly shown that premature closure of the epiphyseal plate of the femoral head was associated with a marked reduction of the ATD which signified an overgrowth of the greater trochanter. *Edgren* was also able to state that abductor insufficiency in coxa plana may develop at a very advanced stage of the disease as a result of elevation of the greater trochanter.

From the dense lines often appearing in the metaphysis of the upper end of the femur in children it appears that the growth in length of the capital metaphysis is almost twice the growth of the trochanteric metaphysis. Using tetracycline labelling in experiments with pigs *Salenius* showed that the difference in growth in length of the capital and the trochanteric metaphyses is associated with a reverse difference in growth of the head from the articular cartilage and that of the greater trochanter from the cartilage covering its cranial surface (Figure 11). As a consequence of this it can be stated that about one half of the growth in length of the greater trochanter can be arrested by epiphyseodesis.

MATERIAL

From November 1957 to the end of 196[illegible] epiphyseodesis of the greater trochanter was performed in 109 cases on 117 hips. In thirty of these cases the indication for this procedure was *moderate infantile coxa vara*, and *threatening overgrowth of the greater trochanter in coxa plana* in thirty two cases. In forty-seven cases

the indication was disturbance in the growth of the capital epiphyseal plate after closed or open reduction of congenital dislocation of the hip (CDH)

The estimation of the beneficial effect of epiphyseodesis of the greater trochanter in preventing insufficiency of the abductors of the hip in the individual case is made difficult by several factors The degree and the course of the growth disturbance of the capital epiphysial plate which is decisive for the degree of threatening overgrowth of the trochanter cannot be estimated by radiography with any certainty Owing to the manner of growth of the trochanter a disadvantageous course of reduction of the ATD in a case with a severe disturbance of growth in the capital epiphyseal plate is reduced but not completely stopped by the epiphyseodesis Proof of the effect of the operation in a group of cases can thus be established by proving a definite change in the course of the reduction of the ATD after the operation

Only the group of cases of CDH in which epiphyseodesis of the greater trochanter was performed was found to be both large and uniform enough to permit statistical evaluation of the degree of the effect of the operation

Data concerning the cases of infantile coxa vara in which epiphyseodesis of the greater trochanter was performed are given in Table 1 Figures 6 and 7 show radiographs of two of these cases The disturbance in the growth of the head and neck of the femur varies very much in cases of moderate infantile coxa vara This makes the estimation of the effect achieved by epiphyseodesis of the trochanter unreliable However when progression of varus threatens the operation is indicated in this group of cases as an alternative to osteotomy

Data concerning the cases of coxa plana in which the operation had been carried out are shown in Table 1 Figure 8 shows radiographs of one of these cases Serial radiographs of this case had shown gradual reduction of the ATD in the affected left hip before epiphyseodesis of the greater trochanter was carried out at the age of eleven years At the age of twelve years the ATD was still + 4 millimeters The development of a condition similar to that seen in Figure 5 B was prevented by the operation

EPIPHYSEODESIS OF THE GREATER TROCHANTER INDICATED BY GROWTH DISTURBANCE IN THE CAPITAL EPIPHYSEAL PLATE AFTER TREATMENT FOR CDH

Some general data concerning the cases of CDH in which epiphyseodesis of the greater trochanter was carried out are given Table 1 In this group an attempt was made to evaluate statistically some of the data connected with the degree of overgrowth of the trochanter and the effect of the operation

It is known that the capital epiphyseal plate contributes about 30 per cent of the growth in length of the femur Although operations carried out for reduction of CDH particularly derotation osteotomy of the femur stimulate growth in the distal end of the femur discrepancy of leg length in unilateral cases of CDH can be expected to depend on the

degree of growth disturbance in the capital epiphyseal plate. In the group of unilateral cases it could be shown that the degree of overgrowth of the greater trochanter on the affected side roughly corresponded to the degree of discrepancy of leg length (Table 2).

Table 1. Age and sex distribution of the cases in which epiphyseodesis of the greater trochanter was carried out

	Total number	Girls	Boys	Op before 5 years of age	Op at 5–6 years	Op at 6–7 years	Op at 7–8 years	Op at 8–9 years	Op at 9–10 years	Op at 10–11 years	Op at 11–12 years	Op at 12–13 years	Op at 13–14 years
CDH	47	36	11	2	2	5	3	9	[illegible]	5	8	3	3
Coxa plana	32	6	26	–	–	–	1	–	3	5	6	[illegible]	12
Infantile coxa vara	30	14	16	–	–	1	2	3	6	6	1	3	8
Bilaterally operated	8	5	3	–	–	1	–	–	1	2	1	1	2
Reoperated (Age at first operation tabulated)	12	8	4	2	1	–	–	1	3	1	3	–	1

Table 2. The correlation between the articulo-trochanteric distance (ATD) and leg length differences of sound and affected sides in unilateral CDH

ATD difference mm	Number of observations	Mean of the leg length difference in mm
5–6	9	7
7–8	4	8
9–10	8	9
11–12	14	9
13–14	11	13
15–16	11	15
17–18	11	11
19–20	[illegible]	14
21–22	11	16
23–24		22
25–26	7	18

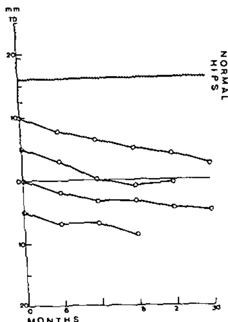


Figure 12 At the top of the figure the mean of the ATD of a healthy hip during the observation period has been indicated This value has been given as 16 mm Above and below it are given the values according to standard deviation calculated as 3 5 mm It was observed that the mean ATD in girls between the ages of 5 13 years was 16 mm ±3 6 mm within the 95 per cent probability limits of 9–23 mm The corresponding value of ATD in boys were 23±4 5 mm with 95 per cent probability limits of 14 32 mm This difference was statistically highly significant (P < 0.01) in spite of the fact that the number of boys was very small The curves in the lower half of the figure indicate the development of ATD in affected hips in CDH before operation during the observation period of 18 30 months The curves have been given according to the first value of ATD recorded in a particular case for those with the first recorded value of ATD of +10 mm +5 mm 0 mm and —5 mm The curves represent the means of observations in each group

The harmful effect of overgrowth of the greater trochanter manifests itself in a positive Trendelenburg sign caused by insufficiency of the muscles responsible for abduction of the hip The relationship of a positive Trendelenburg sign to the length of the ATD is tabulated in Table 3 on the basis of 201 observations It appeared that the Trendelenburg sign was positive in more than half of the cases when the ATD was reduced to less than —5 millimeters

The upper half of figure 12 shows the ATD and variations in the

normal hips of the patients with unilateral CDH. The age distribution of the cases in this group was from four years and eleven months to fourteen years. The fact that the ATD of normal hips measured from radiographs remains fairly constant irrespective of age depends partly on the gradual ossification of the cartilaginous part of the tip of the trochanter.

Table 3. Correlation between ATD on the affected side and the percentage of positive Trendelenburg sign observations in cases of unilateral CDH in girls.

ATD mm	Number of observations	Trendelenburg + per cent
14 – 16	22	27
11 – 13	27	41
8 – 10	26	35
5 – 7	26	19
2 – 4	22	25
−1 – +1	17	26
−4 – −2	16	34
−7 – −	14	57
−10 – −8	12	62
−13 – −11	11	86
−16 – −14	9	100

As it was observed that the ATD was somewhat higher in boys than in girls, the correlation was estimated differently in both groups. However, the number of boys was so small that no statistical evaluation of observations was possible. The table shows clearly how most of the observations of Trendelenburg sign become positive when the value of ATD falls below −5 mm, i.e. when the greater trochanter grows 5 mm over the level of the upper limit of the femoral head.

The ATD of the pathological hips in this series have been divided into four groups represented by the four descending curves in Figure 12. The curves show the gradual reduction of the ATD in thirty-six reduced hips with a disturbance in the growth of the capital epi-

Table 4

The change in development after operation is expressed in differences between the preoperative value and the value at operation on one side and the value at operation minus the value 24 months after operation. If the former was greater the change in development has been given as positive and in other case negative. It was observed that the change was positive in 22 cases and negative in 7 cases. This difference is statistically highly significant ($P < 0.01$) and indicates the positive result of the operation. Cf. Figure 13.

Table 4 The development of ATD on the affected side in 29 cases of CDH 24 months before and after epiphyseodesis of the greater trochanter (Values interpolated from two consecutive observations)

	24 months before operation	At operation	24 months after operation	Preoperative value minus value at operation	Value at operation minus postoperative value	Development
	18 0	7 0	6 0	—11 0	— 1 0	+
	15 4	9 0	11 2	— 6 4	+ 2 2	+
	14 0	3 0	— 5 0	- 11 0	— 8 0	+
	11 0	2 0	— 0 8	— 9 0	— 1 -	+
	7 8	2 0	+ 1 2	— 5 8	— 0 8	+
	7 0	2 0	1 4	5 0	— 0 6	+
	- 2 5	— 0 6	2 6	+ 2 2	— 2 0	−
	6 0	3 0	6 3	— 3 0	+ 3 3	+
	5 2	2 0	0	— 3 2	- 2 0	+
	11 0	— 3 0	1 2	—14 0	+ 4 2	+
	4 0	— 1 0	— 5 0	— 5 0	— 4 0	+
	3 3	— 3 0	— 2 4	— 6 3	+ 0 6	+
	1 4	— 2 0	— 2 2	— 3 4	+ 0 2	+
	0 8	— 4 5	—13 0	— 5 3	— 8 5	—
	0 5	— 2 4	— 9 6	— 1 9	— 7 2	—
	- 0 9	— 3 0	— 4 0	— 2 1	- 1 0	+
	1 5	— 3 0	— 1 4	— 1 5	+ 1 6	+
	- 1 6	— 4 0	— 5 4	— 2 4	— 1 4	+
	1 8	— 3 0	— 4 0	— 1 2	— 1 0	+
	11 0	— 6 0	— 7 0	—17 0	— 1 0	+
	5 0	— 5 0	— 7 0	—10 0	— 2 0	+
	4 0	— 7 0	—15 0	—11 0	— 8 0	+
	2 5	— 9 0	—12 0	— 6 5	— 3 0	+
	3 0	—10 0	—11 0	—13 0	- 1 0	+
	2 6	— 7 0	—13 8	— 4 4	— 6 8	—
	6 1	1 5	—14 4	— 6 4	— 1 9	+
	7 8	—14 0	—22 2	— 6 2	— 8 2	—
	- 15 1	—22 0	—29 0	— 6 9	— 7 0	—
	3 4	— 11 0	—24 0	— 7 6	—13 0	—
R_1	7 8	(—0 6 +9 0) 2 0	1 2	9		
R	0 2	(—4 5 —1 0) 3 0	- 4 5	10		
R_3	—2 5	(2 0 —5 0) —9 5	—12	10		

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TECHNIQUE OF OPERATION

The greater trochanter is exposed by a lateral longitudinal incision through the tractus iliotibialis The periosteum or the cartilage on the lateral aspect of the greater trochanter and the uppermost part of the vastus lateralis muscle are incised longitudinally to the bone proximal and distal to the epiphyseal plate of the trochanter The edges of the periosteum and the cartilage are freed from the bone of the epiphysis and the metaphysis and from the cartilaginous plate by sharp dissection to ensure a complete covering of denuded bone by these tissues at closure of the wound

A piece of bone with a piece of the cartilaginous plate in the middle is chiselled out a m Phemister Anterior and posterior to this piece the peripheral part of the plate is exceed along a distance of about half a centimeter The epiphyseal plate of the trochanter with adjacent epiphyseal and metaphyseal bone is removed with a sharp spoon leaving only the peripheral parts connecting the metaphyseal cortex to the epiphysis To allow destruction of the plate under direct vision the bone and the cartilage should be removed and preserved in plasma or saline solution until destruction is completed Then the bone and cartilage tissue removed are replaced in the cavity and the piece of peripheral bone and cartilage is reinstated The periosteum is carefully sutured by a running catgut suture and should completely cover the bone

During the operation the spread of bone chips around the trochanter and the formation of haematoma under the tractus iliotibialis should be avoided Otherwise large callus formation around the trochanter may occur

Postoperative immobilisation is not necessary

CONCLUSIONS

Judging from the experience gained from 109 cases in which epiphyseodesis of the greater trochanter was carried out at an age varying between four years and eleven months and sixteen years the operation is indicated when serial radiographs have shown a *marked reduction* of the articulotrochanteric distance (ATD) as a result of growth disturbance in the capital epiphyseal plate of the femur in moderate infantile coxa vara in coxa plana and in congenital dislocation of the hip after closed or open reduction Although permanent fusion of the epiphysis to the metaphysis may be difficult to achieve at the age of

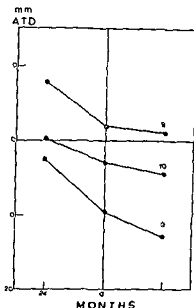


Figure 13 The recorded values of ATD 24 months before and after operation and at operation which are given in Table 6 have been divided into three groups according to the value at operation Thus the 9 cases with highest values at operation are given as the first group the following 10 as the second and the last 10 as the third The curves represent the means of these values and thus indicate the development of ATD in each group before operation and the change in development after operation during the observation period of 24 months before and after operation This change was given as plus or minus in Table 6 In the graphical presentation it appears as clearly positive in all groups

physeal plate The curves represent the periods during which the patients were followed before epiphyseodesis of the greater trochanter was carried out A reduction of the ATD by 4–6 millimeters in two years seems to be a common course in such cases From the curves seen in Figure 13 it appears that the course of development of the ATD over a two year period before epiphyseodesis of the trochanter was a reduction of it by 3–7 millimeters in two years The course of development after the operation was a reduction of 1–4 millimeters in two years The effect of the operation in reducing the overgrowth of the greater trochanter is also apparent from Table 4

Figure 9 shows an example of the effect of epiphyseodesis of the greater trochanter in a case in which the growth of the head and neck of the femur were disturbed after a Colonna operation Without reduction of the growth of the trochanter by epiphyseodesis the ultimate result in this case would have been similar to that seen in Figure 2 b

dazu eine infantile coxa vara bei 32 Fallen waren es Wachstumsveranderungen des Schenkelkopfes und halses bei einer coxa plana bei 47 Fallen eine ahnliche Wachstumsstorung als Folge einer angeborenen Huftgelenksverrenkung (CDH) Die Operation wurde auf Grund der Erfahrungen vorgeschlagen die man durch die Beobachtung der Wachstumsstorungen bei CDH gewonnen hatte (Abbildung 1–4) Zu starkes Wachstum des grossen Trochanters als eine Folge der Wachstumsstorung in der Epiphysenplatte des Schenkelkopfes konnen eine Abduktorinsuffiziens verursachen und einen hinkenden Gang Dies kann durch eine Epiphyseodese des grossen Trochanter verhindert werden wenn die Operation zeitig genug durchgefuhrt wird

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five to seven years the operation is definitely indicated in this age group. At the end of the growth period the possibilities of preventing the appearance of abductor insufficiency by this operation may have been lost.

SUMMARY

Between 1957 and 1965 epiphyseodesis of the greater trochanter was carried out in the Orthopaedic Hospital of the Invalid Foundation in 109 cases. In thirty of these the indication was moderate infantile coxa vara, in thirty-two cases it was growth disturbance of the head and neck of the femur in coxa plana, and in forty seven cases a similar growth disturbance following reduction of congenital dislocation of the hip. The operation was introduced on the basis of experience obtained from the observation of growth disturbances seen in CDH (Figures 1–4). Overgrowth of the greater trochanter as a sequel of growth disturbance in the capital epiphyseal plate of the femur may cause abductor insufficiency and a limping gait. This can be prevented by epiphyseodesis of the greater trochanter if the operation is performed early enough.

RÉSUMÉ

Entre 1957 et 1965 une épiphyséodèse du grand trochanter a été pratiquée à l'Hôpital Orthopédique de la Fondation des Invalides dans 109 cas. Dans 30 de ceux ci l'indication était un coxa vara infantile modéré, dans 32 cas c'était un trouble de croissance de la tête et du col du fémur en coxa plana et dans 47 cas un trouble similaire de la croissance consécutive à la réduction d'une dislocation congénitale de la hanche.

L'opération a été conçue sur la base de l'expérience acquise par l'observation des troubles de la croissance constatés dans la dislocation congénitale de la hanche (Figure 1–4). Une supercroissance du grand trochanter comme séquelle d'un trouble de croissance de la plaque épiphysaire de la tête du fémur peut causer une abduction insuffisante et un boitillement. Cela peut être prévenu par l'épiphyséodèse du grand trochanter si l'opération est pratiquée assez tôt.

ZUSAMMENFASSUNG

Zwischen 1957 und 1965 wurde bei 109 Fällen im Orthopädischen Krankenhaus der Invalidenstifung eine Epiphyseodese des grossen Trochanter durchgeführt. Bei dreissig Fällen davon war die Indikation



Figure 1. Posttraumatic necrosis of the head of the femur. Female, age 42 years. Radiograph taken before implantation of an endoprosthesis. Figures 2 and 3 show the same hip.

were pain in the hip occurred. On October 23 the sedimentation rate of the blood was 33 millimeters per hour. There was slight leucocytosis and fever.

Inflammation of the hip was diagnosed and a course of Chloramphenicol was immediately instituted. A few days later the patient started to feel pain and notice swelling in both ankles and in the metatarso-phalangeal joint of the right big toe. The Latex test was positive, the content of uric acid in the blood was normal. After two weeks treatment the hip was almost free of symptoms. The diagnosis was still open.

In December 1962 the symptoms from the hip recurred. On January 11, 1963 the left hip was punctured and from the thick fluid obtained *Salmonella Newport* was cultured. Cultures from faeces and urine were negative. The Widal test for Salmonella Newport was positive (+1/160).

In cooperation with bacteriologists and epidemiologists different kinds of conservative treatment were tried over a period of one and a half years. In spite of this Salmonella Newport was cultured eleven times from fluid obtained by puncture of the joint between January 11, 1963 and July 30, 1964.

The bacterium was several times shown to be sensitive to Chloramphenicol, Tetracycline, Streptomycin and Sulfa drugs. Protracted courses of these drugs and of Ampicillin (Doktacillin) were tried with some effect on the symptoms

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HAEMATOGENOUS SALMONELLA INFECTION AROUND A METAL HIP ENDOPROSTHESIS

By

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When infection occurs around a metal implant used in orthopaedic surgery, it is mostly a result of inoculation of bacteria during operation. However, we have seen signs of infection appearing around implanted metal appliances more than eight months after primary wound healing without any signs of inflammation immediately after operation. In such cases the question arises whether there is a risk of haematogenous infection in the tissues situated close to a metal implant which is greater than in other parts of the body. When infection with common bacteria occurs close to a metal implant even years after surgery, it can seldom be proved whether inoculation has taken place at the operation or not.

In the case described, a Salmonella infection arose around a Vitallium endoprosthesis three and a half years after implantation of the prosthesis.

CASE REPORT

A woman aged forty-two years sustained a traumatic dislocation of the left hip in 1954. After reduction the hip was free of symptoms for about one year. In 1958 necrosis of the femoral head was clearly evident on the radiograph. On May 5, 1959, a vitallium hip endoprosthesis of the Thompson type was implanted through an anterior incision. Figure 1 shows a radiograph of the hip taken one day before the operation.

The hip was free of pain for three and a half years after the operation. The patient represented an ideal functional result of implantation of a hip endoprosthesis. Figure 2 shows the hip one year and nine months after the operation.

During a visit to a Mediterranean country in August and September 1962 the patient suffered from a gastro-intestinal infection of an undefined nature. After this there had been some pain in the left hip. On October 21, 1962, fever and acute

with a cane Recently in January 1967 she has asked for the insertion of a new endoprosthesis but the risk of flare up of Salmonella infection is evident In addition the acetabulum is too irregular to guarantee a good result

DISCUSSION

There seems to be no doubt that the Salmonella infection around the hip endoprosthesis in the case described arose on the haematogenous route After three and a half years of excellent functioning of the hip symptoms and signs of inflammation appeared in it soon after a gastro intestinal infection sustained in a Mediterranean country Salmonella Newport infection has very seldom been seen in Finland and in 1959 when the endoprosthesis was implanted this bacillus had not been cultured from any patient in the country The same was true in the years that followed until the bacillus was cultured from our patient in 1963

The tendency of Salmonella infections to spread in the body on the haematogenous route is well known Staphylococci as well as other bacteria have this tendency in varying degrees Osteomyelitis due to Salmonella infection is frequently seen but Salmonella arthritis is rare (*Reeves & Churchill Davidson* 1964) When typhoid arthritis appears it has a special predilection for the hip (*Greets* 1964) In 1965 *Weinstein & Kaplan* reported a case in which Salmonella bacteremia was associated with infection of the aorta in the area at which a Hufnagel valve had been implanted four years earlier for mitral insufficiency They pointed out that bacteremia seems to be especially ominous when such a prosthesis is present

Probably there are special reasons to protect persons who have had large metal appliances implanted in any part of the body against haematogenous spread by antibiotics when bacteremia is present or threatening

We have seen infections around Vitallium appliances even around hip endoprostheses heal without removal of the metal piece when the virulence of the bacteria has been very low Protracted conservative treatment in this case thus seemed justified especially when the patient refused removal of the prosthesis However possibly a better acetabulum would have remained if the metal had been removed at an earlier stage thus leaving better possibilities for a later insertion of a new prosthesis

Even where staphylococci are concerned the insertion of an endoprosthesis in a formerly infected hip joint carries a risk of the flare up



Figure 2. The hip one year and nine months after insertion of the endoprosthesis. Normal range of motion. No limp. No pain.

Figure 3. The hip one-and-a-half years after haematogenous infection by Salmonella Newport. The prosthesis is protruding into the pelvis. Resorption of bone around the shaft.

but without eradication of the infection. Continuous irrigation of the joint with Streptomycin for eight days, a prolonged course of injections of autovaccine prepared from the Salmonella Newport culture and a course of small doses of arsenic were tried without effect. No fistula opened from the joint during the whole period of observation.

Slight destruction of bone at the joint surface of the acetabulum was seen on the radiograph in January 1963. In May 1964 the endoprosthesis had protruded into the pelvis and there was resorption around the shaft of the prosthesis (Figure 3). The endoprosthesis was removed on August 13, 1964. The patient had refused earlier removal of it because the symptoms varied and weightbearing of the hip was possible for long periods.

Culture from the joint fluid was negative in February 1965 and no signs of inflammation have occurred since then. The patient is walking without pain but

nach einer gastro intestinalen Infektion auf Die Spezifität der Bakterie war ein Beweis dafur dass die Infektion der Hüfte auf dem haematogenem Weg entstanden war Die Entfernung der Prothese war unvermeidlich da alle andere Behandlung vergebens war

Die Moglichkeit einer haematogenen Infektion in der Umgebung von grossen Metallimplantaten kann prophylaktische Massnahmen motivieren wenn ein Risiko für Bakteriämie von allgemeinen oder lokalen Infektionen vorhanden ist

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of infection. In a patient treated by us a staphylococcus infection flared up after application of a Vitallium hip endoprosthesis when the infection had been quiescent for years. In 1953 *A. Langenskiöld* reported a case in which a Salmonella Paratyphi B infection flared up in silk granulomas in the abdominal wall two years after cholecystectomy for carrier state. Cases of Salmonella osteomyelitis flaring up after decades of quiescence have also been seen.

SUMMARY AND CONCLUSIONS

A Vitallium hip endoprosthesis had been implanted in a woman for posttraumatic necrosis of the head of the femur. Salmonella Newport infection around the prosthesis occurred following gastro-intestinal infection three and a half years after the operation. The specifity of the *bacterium proved that the infection of the hip had arisen on the* haematogenous route. Removal of the prosthesis was inevitable because all other treatment failed.

The possibility of haematogenous infection around large metal implants might deserve special prophylactic measures when there is a risk of bacteremia from general or local infections.

RÉSUMÉ

Une endoprothèse de la hanche en vitallium a été implantée chez une femme en raison d'une nécrose post-traumatique de la tête du fémur. Une infection de Salmonella Newport autour de la prothèse se manifesta à la suite d'une infection gastro-intestinale trois ans et demi après l'opération. La spécificité des batéries prouva que l'infection de la hanche s'était produite par la voie hématogène. *Le retrait de la* prothèse était inévitable, tous les autres traitements s'étant montrés vains.

La possibilité d'une infection hématogène autour d'une large implantation métallique requiert des mesures prophylactiques spéciales lorsqu'il y a danger de bactériémie d'infection générale ou locale.

ZUSAMMENFASSUNG

Bei einer Frau, in die dreiundeinhalb Jahren früher eine Vitallium Hüftendoprothese wegen einer posttraumatischen Femurkopfnekrose implantiert wurde, trat eine Salmonella Newport *Infektion der Hüfte*

urfaces in extension and at different angles of flexion The radiographic enlargement was compensated for Six to eight positions of the knee from extension to about 90 flexion were examined on 5 subjects and two or three positions on the others

MECHANICS OF THE KNEE JOINT

The movements of the knee joint are usually regarded as a combination of rocking and gliding with the first 20 of the flexion a pure rocking movement and the rest a glide (1 2 7 9 10) These movements which occur in the sagittal plane are sometimes accompanied by a simultaneous rotary movement the terminal stage of which is said to be obligatory It has been shown by Hallén & Lindahl (5) however that the terminal rotation is variable and not compulsory In this study account was taken only of the movement in the sagittal plane By definition in a pure rocking movement new points of the two articular surfaces (of the femur and tibia) constantly come into contact with each other in equidistant points If the points are not equidistant the movement is a combination of a rocking and gliding Finally if new points on one surface (the femur) constantly come into contact with the same point on the other surface (the tibia) there is pure slipping

In active extension of the knee joint the force exerted by the quadriceps acts *via* the patella and the ligamentum patellae pulls on the tuberosity of the tibia (X in Figure 1) Resistance to this movement may occur or be applied at any points on the tibia but usually it acts peripherally For instance in extension of the knee against a resistance with the subject supine the force is usually applied just above the ankle In this study the forces acting in the knee joint were calculated on the assumption that the force (*R*) resisting extension was applied 30 cm distally to the joint space The same site was used in a simultaneous examination of the maximum force of extension in the sound knee joint The forces will depend on the point at which the resisting force is applied

If a tractive force is applied to the tuberosity of the tibia at the same time as a resisting force 30 cm peripherally on the tibia the articular surfaces of the tibia and the femur will be pressed together If the surfaces were congruent this compressive force would be distributed uniformly over them but otherwise it will act in the line of contact as in the case of a cylindrical surface in contact with a plane The force arising between the articular surfaces is usually referred to as the normal force (N) and it acts perpendicular to the tangent at the point

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THE MECHANICS OF EXTENSION OF THE KNEE JOINT

By

O. LINDAHL and A. MOVIN

Received 3.V.66

From a purely mechanical aspect the function of the knee joint is of great interest since its impairment is a common orthopaedic problem. In a series of studies conducted at the Department of Orthopaedics at Umeå special attention has been devoted to this joint (3–6, 8). The object of the present one has been to examine the movements that occur between the articular surfaces and the forces involved in active extension of the knee.

MATERIAL

The knee joints of 15 healthy subjects were examined radiographically and a follow-up of some 30 arthrographic examinations of the knee was performed in order to localize the position and insertion of the anterior cruciate ligament.

METHODS

On the models of the knee obtained from sagittal radiographs of the joint in positions from extension to about 90° flexion ordinary methods of calculation used in mechanics were applied. The film focus distance was 70 cm and the enlargement factor was 1.08. To facilitate identification of the patellar ligament and the distal part of the anterior cruciate ligament a low kilovoltage exposure was used.

From the arthrograms it was found that the insertion of the anterior cruciate ligament in the intercondylar groove of the femur was usually half a centimetre from the posterior limit of the groove. The accuracy of this estimate could be checked, it being assessed on the same knee in both extension and 90° flexion. The distance between the two ends of the ligament should be the same and this was the case within 2–3 mm. With the positions of the two ends of the ligament known its direction could then be determined.

For each subject the points of contact between the tibia and femur were drawn in for the various positions of the knee joint examined. In addition the distances between the points of contact were measured on the tibial and femoral articular

force that prevents the tibia from being displaced forwards this force is most likely to be located in the anterior cruciate ligament (A) the prime function of which is to prevent forward displacement of the knee joint (the drawer effect will be positive when the ligament is ruptured) With moderate loads the collateral ligament and capsule will contribute to the stabilization of the joint but when larger forces are acting it is logical to suppose that the forward force will be taken up largely by the anterior cruciate ligament

To be able to calculate the relations between the 4 forces (N A N and R) acting on the tibia when the knee is extended it is necessary to know their direction and the points on the tibia at which they are applied If one of the forces is determined experimentally it is possible from these relations to calculate the magnitudes of the other 3

The various forces acting on the tibia are shown in Figure 1 When equilibrium obtains the clockwise and anticlockwise moments about any point will be equal and from this relationship an equation can be derived for each of the points If the tuberosity of the tibia is the point about which moments are taken we have with the notation in Figure 1 $Ra = Nb - Ac$ (The line of action of the force exerted by the ligamentum patellae passes through the point and its moment is therefore zero) By taking moments about 2 other points namely the insertion of the anterior cruciate ligament and the point of action of the normal force on the tibia 3 expressions are obtained from which the ratios between the various forces can be derived (N/R N/R A/R)

RESULTS

Movements in the Joint

The displacement of the patella in relation to the femur (*i e* the elongation of the quadriceps) during flexion for a subjects is represented graphically in Figure 2 and the mean curve (I) is given in Figure 3 The fact that this is nearly straight means that *the elongation of the quadriceps is proportional to the decrease in the angle of the knee joint*

Curves II and III in the same figure show the mean relationship between the displacement of respectively the points of contact on the femur and tibia and the angle of *the knee joint* Throughout flexion the femur described a movement such that *new points* on it constantly came into contact with the surface of the tibia (curve II) During the first 20 of the flexion the *same type* of movement occurred with the

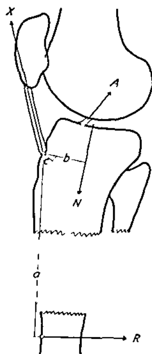


Figure 1. Diagram drawn from a radiograph of the knee joint showing the forces acting on the tibia in extension. X. Traction of the ligamentum patellae. A. Traction of the anterior cruciate ligament. N. Normal force acting on the tibia at its point of contact with the femur. R. The force with which the distal part of the lower leg 30 cm below the knee is pressed forwards in extension.

of contact. As the tibial and femoral condyles are not congruent at any stage of the movement the force will in theory act more or less in a line, but since the cartilage is soft and the menisci occupy part of the space between the incongruent surfaces the force will in practice be distributed over an area about the theoretical line of contact, which in the sagittal plane will be seen as a point. From the mechanical aspect the normal force may be considered to pass through the point of contact between the articular surfaces. When the cartilage is normal and of uniform thickness this is the point at which the distance between the radiographic contours of the articular surfaces is a minimum. At its posterior limit the radius of the femoral condyles is small and the point is easy to find, but at its anterior limit the radius of the femoral condyle is considerably larger and the point is then more difficult to locate.

The 3 forces under discussion, namely the pull on the tuberosity of the tibia, the force of resistance acting peripherally on the tibia and the normal force, are not in equilibrium. Moreover there must be a

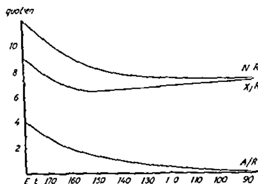


Figure 4 Mean relati n between the angle of flexion and the ratio N/R X/R and A/R (see also F gure 1)

If there were a pure rocking movement the 2 lower curves would coincide which they do not at any phase of the flexion

Forces Acting in the Joint

By means of the above equation the relations between the 4 forces were calculated for each position of flexion and each subject Since the extremely large volume of data so obtained is not of general interest only the means are reported here The mean ratios of these forces for the various flexion positions are given in Figure 4 The curve for X/R shows the moment exerted by the quadriceps when a resistance was applied 30 cm below the joint space It is seen that between 90 and 160 the force was largely constant but in the last 20 of extension the ratio X/R rose from about 6 to a mean of 9 The individual values in extension ranged from 7 to 12

The curve for the ratio A/R shows that in extension the cruciate ligament is subjected to fairly large forces but as the flexion is increased these approach zero here the ligament is not required to prevent a forward displacement of the tibia Thus in this position the other 3 forces are largely in equilibrium

It is seen from the curve for the ratio N/R that the force between the articular surfaces is fairly constant from 90 to 160 and then rises for the last 20 of the extension Througout the movement this pressure is greater than the pull on the tuberosity of the tibia

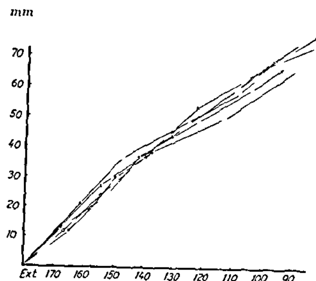


Figure 2 Relation between the displacement of the upper border of the patella (elongation of the quadriceps) and the angle of flexion of the knee for 5 subjects

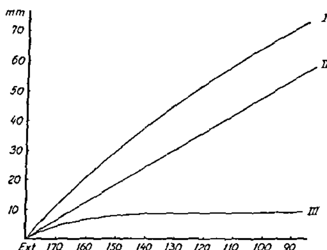


Figure 3 (I) Mean relationship between the angle of flexion and elongation of the quadriceps (II) Displacement of the points of contact on the femur (III) Displacement of the points of contact on the tibia

tibial condyle in relation to the femur new points on the tibia constantly making contact with the femur (curve III) After a flexion of 20–30 the curve turns parallel to the axis of x which means that the same point on the tibia slipped on the femur These findings combined show that during the first 20 30° of the flexion movement there was a combination of rocking and gliding and not a pure rocking movement as is commonly supposed After this position there is pure gliding of the femur against the tibia

instance water losses due to postmortem changes but such alterations are not involved in the present context

As regards the exactness with which the various points on the radiographs can be determined it is clear that small errors of estimation may have been incurred In 5 of the subjects the points of contact between the tibia and the femur (which are the most difficult to determine accurately) were inserted for each point the most correct point and 2 extreme positions in front and behind were marked The quotients of the forces were then calculated for all 3 points The range of the 3 values so obtained was not so great as to affect the conclusions materially It was found that the most correct" points lay very near to midway between the 2 extreme values and were thus correctly placed

In the anatomic literature it is stated that the medial condyle of the femur is slightly larger than the lateral one and that their curvatures are not exactly equal This was confirmed on the radiographs The differences in shape were small however In the determination of the curves and points in the sagittal plane they were taken midway between the 2 contours when the condyles were not completely congruent

SUMMARY

On the basis of radiographic examinations of the knee joints of 15 healthy subjects the relative movements of the articular surfaces were examined During the first 20–30 of flexion there was combined rocking and slipping after which there was pure slipping of the femur on the tibia There was no pure rocking movement From the direction and location of the various forces acting on the knee joint in active extension the ratios between the forces were calculated It was found that from 90 to 160 the leverage exerted by the quadriceps remained fairly constant but then decreased so that a greater effort was required to extend the joint through the last 20

RESUME

Sur la base d examens radiographiques de l articulation du genou chez 15 sujets sains il a ete etudie les mouvements relatifs des surfaces articulaires Durant les degres 20 a 30 de flexion il y avait une combinaison de tremblement et de glissement apres quoi il y avait un pur glissement du femur sur le tibia On n a pas observe de pur tremblement En partant de la direction et de la localisation des differentes

DISCUSSION

Since the purpose of this study was to examine the function of the knee joint as a mechanical system, means were used although the individual variations were quite large. Interest was centred on the ratio V/R, which governs the action of the quadriceps. This ratio will be less favourable in the extended position chiefly because in the terminal stage the points of contact between the 2 articular surfaces move forwards. In one case in which the knee could be hyperextended by about 15° the leverage was still less favourable and in extension the ratio V/R was 2.5. In the earlier literature (9) calculation of the forces in the knee was based on the moment about an imaginary axis of motion placed in the centre of the femoral condyles. This approach is mechanically unsound, as it does not take account of all the forces acting on the joint, and the rotation does not occur about an axis of small diameter as in the hinge.

In the erect posture the knee can be extended quite easily because the force required in extension decreases as the angle between the femur or tibia and the vertical plane diminishes; for zero angle the required force will be zero. This means that in extension the knee is for the most part stable and need only be balanced. On the other hand, in the supine position and, for instance, in exercising the quadriceps against a resistance, the unfavourable leverage in extension is apparent. The force exerted in the terminal extension will then progressively diminish.

In another study that is being conducted on the forces acting on extension of the knee at different angles, the force in the quadriceps will be calculated from the ratio V/R. A pilot study (8) has shown that the force exerted by the quadriceps falls off more rapidly than would correspond to the decrease in mechanical advantage. This is in accordance with von Schwann's law, which states that a reduction of the muscular force occurs on shortening (about 7 cm from the 90° position to extension).

In judging whether these calculations of the forces are relevant to the vital knee, it is pertinent to consider whether living tissue differs from dead and how accurately the various distances could be determined on the radiographs. So far as is known, the laws of nature, including simple mechanical principles, apply to *all* materials, whether vital or not. In experiments on specimens there can of course be differences in chemical composition, strength and other properties owing to for

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ARTHROGRAPHY OF THE KNEE IN THE DIAGNOSIS OF TORN SEMILUNAR CARTILAGE

By

WALTER EDGREN, ULRIKA HEIKEL-LAURENT & ERIK B. RISKA

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In 1948 *Lindblom* described an excellent technique of arthrography of the knee. Torn cartilage was correctly diagnosed in 95 per cent of his series, but he did not indicate the number of cases in which the diagnosis was verified by operation (3). Subsequently, several papers have been published concerning the value of arthrography in the diagnosis of meniscal injuries. In 1959 *Turner & Wirt* stressed the usefulness of this method in the diagnosis of lesions of the medial meniscus, but stated that it was unreliable where the lateral meniscus was involved (9). Later authors have come to similar conclusions, and in 1965 *Sommer* as well as *Saugman Jensen* stated that the diagnostic value of the arthrography of the knee is doubtful (4, 8). Furthermore, complications have occurred in connection with arthrography (e.g. 6) and the method has therefore abandoned by some orthopaedic surgeons.

Nevertheless, a sound arthrographic technique in combination with judicious interpretation of the findings can be decisive in the diagnosis of a ruptured meniscus. The lack of agreement in the reports hitherto published may be partly attributable to differences in the methods employed, partly to varying experience in interpreting the arthrograms.

At the Orthopaedic Hospital of the Invalid Foundation arthrography of the knee joint has been used for some twenty years as a routine method in the diagnosis of meniscal injuries of the knee. The method of *Lindblom* (3) as modified by Edgren in 1957 is still used in this clinic.

The present contribution (cf. 2, 5, 7) is made in belief that our

forces operant sur l'articulation du genou en extension active il a été calculé le rapport entre les forces. On a constaté que de 90 à 160° le moment du quadriceps reste à peu près constant pour décroître ensuite de sorte qu'un plus gros effort est nécessaire pour étendre l'articulation à travers les derniers 20 degrés.

ZUSAMMENFASSUNG

Auf der Grundlage von röntgenologischen Untersuchungen der Kniegelenke von 15 gesunden Personen wurden die relativen Bewegungen der Gelenksflächen untersucht. Während der ersten 20–30° der Beugung war eine kombinierte Wiege- und Gleitbewegung, hernach reines Gleiten des *Femur* auf der *Tibia* zu beobachten. Alleinige Wiegebewegung wurde nicht gesehen. Aus der Richtung und Lage der verschiedenen *Kräfte die auf das Kniegelenk während aktiver Streckung wirken* wurde das Verhältnis zwischen den Kräften berechnet. Es wurde gefunden, dass von 90 bis 190° die vom Quadriceps ausgeübte Hebelkraft ziemlich konstant war, jedoch dann abnahm, so dass eine grössere Anstrengung notwendig war, um das Gelenk während der letzten 20 zu strecken.

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Table 2

Operative finding	No of cases	Clinical diagnosis correct No of cases	%	Clinical diagnosis incorrect No of cases	%	Arthrography correct No of cases	%	Arthrography incorrect No of cases	%
Lateral meniscus ruptured	39	21	54	18	46	36	92	3	8
Medial meniscus ruptured	95	67	69	28	31	91	95	4	5
Both menisci ruptured	6	0	0	6	100	6	100	0	0
Discoidal meniscus	10	3	30	7	70	10	100	0	0
No rupture seen at operation	15	10	67	5	33	11	73	4†	27
Total	165	101		64		154		11	

Rupture of the meniscus was clinically diagnosed but the fact that both menisci were ruptured was not recognized

† At the operation no rupture of the menisci was observed in spite of clear arthrographic finding (Figure 8)

r n diagnosis could be made on the basis of the history and the physical examination (Table 2) In 69 per cent of the cases the clinical diagnosis of torn medial semilunar cartilage proved to be correct while in the cases showing rupture of the lateral cartilage the clinical diagnosis was correct in only 54 per cent of cases A correct clinical diagnosis of discoidal meniscus was made in 3 cases out of 10 (Table 2) In 10 cases out of 15 the clinical diagnosis of a normal semilunar cartilage was correct These 15 patients were operated on owing to severe symptoms of long standing

TECHNIQUE OF ARTHROGRAPHY

A condition for achieving good arthrograms of the knee is that the *central beam* strikes tangentially on the part of the meniscus to be reproduced In practice this means that in each exposure the central beam must be *parallel with* part of the proximal plane of the tibia The application of this rule *requires acquaintance* with the position of the proximal plane of the tibia and the factors influencing it

In his pioneering monograph on arthrography of the knee using iodine salt aqueous solution *Lindblom* (1948) indicated certain standard projections to be used in arthrographic In our opinion based on experience gained at the Orthopaedic Hospital of the Invalid Foundation these standard projections do not invariably yield the best possible results because *this method* does not sufficiently reckon with variations in the position of the proximal plane of the tibia in relation to its longitudinal axis (see Figure 1 *and*) and on the mobility of the knee joint or hyperextension or extension deficiency

In order to obtain reliable information regarding the position of the proximal plane of the tibia in relation to the tabletop each arthrography of the knee is

results may throw further light on the value of arthrography in the diagnosis of torn semilunar cartilage. At the same time *Lindblom's modified method* is presented.

MATERIAL

The results are based on analysis of 10[illegible] patients operated on for meniscal injuries or discoidal menisci in the Orthopaedic Hospital *of the Invalid Foundation* during the years 1957–1964. Prior to operation all patients were examined by arthrography. During the period in question more than 700 arthrograms were taken in order to *diagnose injuries of the knee* but the material presented here consists solely of operated cases in which the condition of the *semilunar cartilage* was examined carefully at the operation. Of these patients 59 were men and 106 were women. Seven patients were under 15 years of age at the time of operation.

OPERATIVE FINDINGS

According to the operative records 95 patients had torn medial semilunar cartilage. The lateral cartilage was *ruptured in* 39 cases and *both* menisci were ruptured in 6 (Table 1). It is possible that the actual number of cases with rupture of both cartilages was larger since it is difficult to examine the meniscus on the other side *through an* anterolateral or anteromedial incision. This applies in particular to the posterior horn of the meniscus. Arthrotomy was *carried out by an anterolateral or* anteromedial oblique incision or in some cases by the typical incision of Payr. In 10 cases a discoidal semilunar cartilage was observed and 4 of these were torn. In 15 *cases both semilunar cartilages* were normal showing no signs of rupture (Table 1) but it should be pointed out that the operator may fail to observe a rupture (cf. *Watson Jones*). It is particularly difficult to distinguish a rupture starting from the point of the meniscal wedge.

CLINICAL DIAGNOSIS

In the *present series the clinical diagnosis was verified by the operative finding* in 101 cases (61 per cent). In 64 cases the clinical diagnosis proved to be incorrect.

Table 1. Operative findings

Meniscu	*No. of cases*
Lateral ruptured	39
Medial ruptured	9
Both ruptured	[illegible]
Discoidal	10
No rupture seen at operation	15
Total	1[illegible]

Table 2

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† At the *operation no rupture of the menisci* was observed in spite of clearly arthrographic finding (Figure 8).

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In his pioneering monograph on arthrographs of the knee using iodine salt aqueous solutions *Lindblom* (1948) indicated certain standard projections to be used in the arthrography. In *our opinion based* on experience *gained at the Orthopaedic* Hospital of the Invalid Foundation these standard projections do not invariably yield the best possible results *because* this method does not sufficiently reckon with variation in the position of *the proximal plane* of the tibia in relation to its longitudinal axis (see Figures 1 and 2) and on the motility of the knee joint, *e.g.* hyperextension or extension deficiency.

In order to obtain reliable *information regarding* the position of the proximal plane of the tibia in relation to the table top each arthrography of the knee is



Figure 1. An example of a direction view. The proximal plane of the tibia is tilted 8 degrees.



Figure 2. An example of a direction view. The proximal plane of the tibia is tilted only 2 degrees.

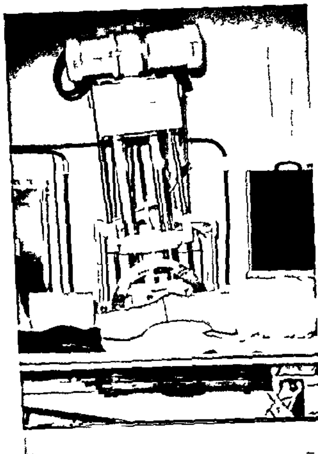


Figure 3 The patient in position for arthrographic examination. There was extension deficiency in the knee joint. The knee is supported with cushions. The joint space is drawn out on the skin according to the direction view and the tube is tilted 5 degrees caudally so that the central ray parallels the proximal plane of the tibia

preceded b th t king of a so called "direction view" (Figures 1 and 2). This is taken with the aid of a movable bystand with horizontal beam direction. The patient is in the supine position with extended legs. The cassette (18 × 24 cm) is placed on edge against the medial surface of the knee with one long side close to the tabletop. If an extension deficiency is present the knee is supported by a cushion to eliminate unsharpness due to motion. On a lateral view thus obtained the angle between the proximal plane of the tibia and the tabletop (= the long side of the film) can be measured directly (Figures 1 and 2). This angle determines the projection to be used in the arthrographic

After local anaesthesia the joints are emptied and then the contrast medium (6 8 cc of 60 per cent Urografin) is injected

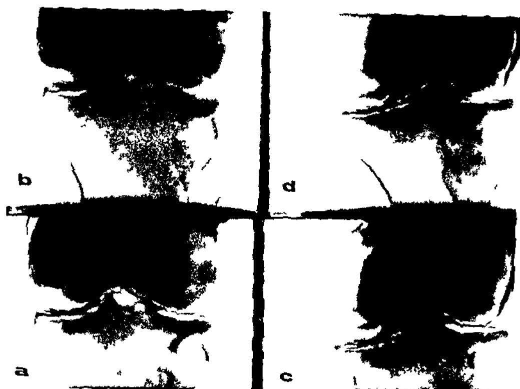


Figure 4 Boy aged 15 Rupture of medial semilunar cartilage In the direction view the proximal plane of the tibia was tilted 2 degrees a and b the right leg in neutral position = position I c and d the leg was rotated 45 degrees outward = position II a X ray tube in neutral position b tube tilted 5 degrees cranially c tube in neutral position d tube tilted 5 degrees caudally Note that the rupture is more clearly visible in the pictures a and d Vertically juxtaposed pictures forms a stereo pair

Exposures are taken in the three basic projections indicated by *Lindblom* I = frontal II = 45-degrees eversion and III = 45 degrees inversion On the basis of the direction view the beam direction is determined by one of the following two methods Either the tube is tilted so that the central ray parallels the proximal plane of the tibia Exposures are taken in this position as well as with further tiltings of 5 degrees cranially and 5 degrees caudally (Figure 3) Or the knee is bent with the aid of cushion so that the proximal plane of the tibia becomes perpendicular to the tabletop and exposures are then taken in neutral position as well as with tilting of 5 degrees caudally and 5 degrees cranially *Our experience suggests that the latter alternative is to be preferred*

Film size 24 × 30 cm was used The picture field was divided into four subfields with the aid of a semi automatic seriograph so that the pictures on the short side of the film formed a stereo pair (Figure 4) In examining children a film of this size can be divided into six subfields Projection IV the tunnel projection has been taken as a ventrodorsal view with the patient still supine and with the knee in about 30 degree flexion over a cushion The cassette 13 × 18 cm is placed crosswise in the popliteal fossa The tube is tilted in the caudal direction and in this



Figure 5 Man aged 24 The proximal plane of the tibia in the direction view was tilt 15 degrees and corrected to vertical with a cushion In Figure 5 a position I tube neutral in Figure 5 b position II tube tilted 5 degrees caudally The medial horizontal rupture is clearly visible The rupture was also diagnosed clinically Verified by operation

case too the degree of tilting must be determined by the direction of the proximal plane of the tibia In the adjustment the direction view" and a mark on the skin indicating as accurately as possible the joint space are very helpful For projection N the lateral projection Lindblom's technique is used

By variation of the degree of eversion and inversion respectively we have been able in some cases to visualize a rupture in the meniscus which had not been seen in the first examination This applies to small ruptures of the horns of the semilunar cartilages

RESULTS

By this modified technique of arthrography a correct diagnosis was made in 154 of the present 16 cases (93 per cent) (Figures 5a and b) In 64 cases in which the clinical diagnosis proved to be incorrect a correct diagnosis was achieved on the basis of the arthrograms in 60 cases (94 per cent) (Figures 6a and b) On the other hand in the group of 1 patients in which no rupture of the semilunar cartilage could be seen at operation the arthrography showed a rupture in 4 cases (Table 2) In these cases the lateral meniscus was involved in three and the medial meniscus in one In one of the former the meniscus was in part detached from the capsule but in the meniscus itself no rupture was detected As revealed by arthrography there was in another of the lateral cases a horizontal rupture which started from the inner margin of the meniscus and was therefore difficult to detect (Figure 8) In the third case the rupture occurred in connection with removal of the meniscus When an attempt was made to remodel the



a



b

Figure 6. Woman aged 35. The proximal plane of the tibia in the direction view was tilted 5 degrees and was corrected to vertical. Figure 6 a, position I with the tube in neutral position. Figure 6 b, position II with the tube tilted 5 degrees caudally. Rupture of lateral semilunar cartilage is clearly seen in both figures. Rupture verified by operation but not diagnosed clinically.



a



b

Figure 7. Woman aged 39. The proximal plane of the tibia was vertical in the direction view. Both figures from projection II. Figure 7 a, tube in neutral position. Figure 7 b, tube tilted 5 degrees caudally. The discoidal lateral semilunar cartilage is clearly seen in Figure 7 b but not in Figure 7 a. Note also the horizontal rupture of the medial semilunar cartilage in Figure 7 b. The arthrographic findings was verified by operation. Clinical examination failed to reveal the discoidal meniscus and the rupture in the medial meniscus.

removed meniscus no rupture was observed, but it may have been overlooked. It should be borne in mind that ruptures sometimes escape discovery at operation (cf. Watson Jones). All 10 cases of discoidal semilunar cartilage were correctly diagnosed by arthrography (Figures 7a and b), and the same holds good for the 6 patients showing rupture of both semilunar cartilages (Table 2).



Figure 8 Man aged 39 A clear horizontal rupture is seen in the lateral meniscus but the operator failed to find it The arthrographic finding is so typical that it is obvious that the operator did not recognize the true condition of the semilunar cartilage

DISCUSSION

Since arthrography performed by the technique described caused no complications in any of over 700 cases the examination must be regarded as harmless The complications reported in the literature are perhaps attributable to technical mistakes On the basis of the present results arthrography seems to be indicated in all cases suspected of torn semilunar cartilage even if the clinical diagnosis appears certain Arthrography makes evaluation of the condition of both semilunar cartilages possible (cf 1) including that which appears to be symptom free If a good arthrogram is available it is possible to plan the operation adequately in cases showing rupture of both menisci Furthermore it should be borne in mind that it is difficult to diagnose a discoidal semilunar cartilage on the basis of the history and the physical examination In such cases arthrography of the knee almost invariably yields a correct diagnosis Finally it should be emphasized that arthrography is a valuable aid in the diagnosis of injuries of the knee in cases in which the information obtained from the history and the physical examination is unsatisfactory

SUMMARY

Arthrography of the knee was performed by a modification of Lindblom's technique in 165 cases in which the condition of the semilunar cartilages was subsequently verified by operation Of the patients



a



b

Figure 6. Woman aged 35. The proximal plane of the tibia in the direction view was tilted 5 degrees and was corrected to vertical. Figure 6 a: position I with the tube in neutral position. Figure 6 b: position II with the tube tilted 5 degrees caudally. Rupture of lateral semilunar cartilage is clearly seen in both figures. Rupture verified by operation but not diagnosed clinically.



a



b

Figure 7. Woman aged 39. The proximal plane of the tibia was vertical in the direction view. Both figures from projection II. Figure 7 a: tube in neutral position. Figure 7 b: tube tilted 5 degrees caudally. The discoidal lateral semilunar cartilage is clearly seen in Figure 7 b but not in Figure 7 a. Note also the horizontal rupture of the medial semilunar cartilage in Figure 7 b. The arthrographic findings was verified by operation. Clinical examination failed to reveal the discoidal meniscus and the rupture in the medial meniscus.

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clinique s'est montré incorrect, un diagnostic correct a été posé sur la base des arthrogrammes dans 60 cas (94 pour cent). Le diagnostic arthrographique ne s'est pas vérifié à l'opération dans 4 cas sur 15 chez lesquels les cartilages semi-lunaires semblaient être normaux, mais il faut se souvenir que le chirurgien peut n'avoir pas observé une rupture du ménisque, notamment s'il s'agit d'une rupture horizontale. Ceci semblait être le cas chez deux des quatre malades en question. Le diagnostic arthrographique était correct dans tous les 10 cas montrant un ménisque discoïdal et dans tous les 6 cas chez lesquels il y avait rupture deux ménisques.

ZUSAMMENFASSUNG

Bei 165 Fällen wurde eine Arthrografie mit einer modifizierten Methode der Lindblom-Technik durchgeführt, wobei nachher die Verhältnisse an den Menisken durch einen operativen Eingriff beurteilt werden konnten. Von den Patienten waren 59 Männer und 106 Frauen. 7 Patienten waren 15 Jahre alt oder jünger.

Die Operationsbefunde zeigten, dass in 95 Fällen der mediale Meniskus, in 39 Fällen der laterale Meniskus, in 6 Fällen beide Menisci rupturiert waren, während 10 Patienten einen discoidalen Meniskus hatten. Bei 15 Fällen schienen beide Menisken normales Aussehen zu haben.

Eine richtige klinische Diagnose wurde in 101 Fällen von 165 (61 pro zent) gestellt. Bei 64 Fällen war die klinische Diagnose falsch.

Die Modifizierung der Arthrografitechnik von Lindblom wird beschrieben. Keine Komplikationen traten im Zusammenhang mit der Arthrografie auf.

Mit dieser modifizierten Methode wurde bei 154 Fällen von 165 (93 pro zent) eine richtige Diagnose gestellt. Von 64 Fällen mit einer unrichtigen klinischen Diagnose konnte eine richtige Diagnose bei 60 Fällen (94 pro zent) auf Grund des Arthrogramms gestellt werden. Die arthrografische Diagnose wurde bei 4 von 15 Fällen nicht bestätigt, bei ihnen schienen die Menisken bei der Operation von normaler Beschaffenheit zu sein. Man sollte sich aber vor Augen halten, dass dem Operateur eine Ruptur des Meniskus entgehen kann, besonders wenn eine horizontelle Ruptur in Frage kommt. Dies scheint in mindestens zwei von den vier Fällen zugetroffen zu sein. Die arthrografische Diagnose war bei allen 10 Fällen mit einem diskoidalen Meniskus richtig und bei allen sechs Fällen mit Rupturen in beiden Menisken.

59 were men and 106 were women. Seven patients were 15 years old or younger.

According to the operative findings the medial meniscus was ruptured in 95 cases, the lateral meniscus in 39 and both in 6, while 10 patients had a discoidal semilunar cartilage. In 15 cases both semilunar cartilages seemed to be normal.

A correct clinical diagnosis was made in 101 cases (61 per cent) out of 165. In 64 cases the clinical diagnosis was incorrect.

A modification of Lindblom's arthrographic technique is described. No complications occurred in connection with arthrography.

By this modified method a correct diagnosis was made in 154 cases (93 per cent) out of 165. In 64 cases in which the clinical diagnosis proved to be incorrect, a correct diagnosis was made on the basis of the arthrograms in 60 (94 per cent). The arthrographic diagnosis was not verified at operation in 4 cases out of 15 in which the semilunar cartilages seemed to be normal at operation, but it should be borne in mind that the operator may fail to observe a rupture in the meniscus, particularly if a horizontal rupture is involved. This seems to apply to at least two of the four cases in question. The arthrographic diagnosis was correct in all 10 cases showing discoidal meniscus and in all 6 cases in which both menisci were ruptured.

RÉSUMÉ

L'arthrographie du genou a été pratiquée par une modification de la technique de Lindblom dans 165 cas chez lesquels l'état des cartilages semi-lunaires a été vérifié par l'opération. Sur ce nombre de malades 59 étaient des hommes et 106 des femmes. Sept malades avaient 15 ans ou moins.

Selon les trouvailles opératoires il y avait rupture du ménisque médian dans 95 cas, du ménisque latéral dans 39, des deux dans 6 cas, alors que chez 10 malades un cartilage semi-lunaire était discoïdal. Dans 15 cas les deux cartilages semi-lunaires semblaient être normaux.

Un diagnostic correct a été posé dans 101 cas (61 pour cent) sur 165. Dans 64 cas le diagnostic clinique était incorrect.

Une modification de la technique de Lindblom pour l'arthrographie est décrite. L'arthrographie n'a donné lieu à aucune complication.

Avec cette méthode modifiée un diagnostic correct a été posé dans 154 cas (93 pour cent) sur 165. Dans 64 cas chez lesquels le diagnostic

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From the Laboratory of Experimental Biology Dept of Anatomy and Dept of Orthopaedic Surgery University of Gothenburg Sweden

OBSERVATIONS ON THE ACTION OF INTRAARTICULARLY ADMINISTERED PREDNISOLON TERTIARY BUTYL ACETATE (CODELCORTONE TBA) AND METHYLPREDNISOLON ACETATE (DEPOMEDRONE) IN THE NORMAL RABBIT KNEE JOINT

A vital microscopic and histologic study

By

P I Brånemark I Goldie & J Lindström

Received 14 IX 66

INTRODUCTION

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Some authors have questioned whether the therapeutic effect of locally administered steroids in joints has been satisfactory *E g Ansell et al* (1956) stated that the one or three year results on treating rheumatoid arthritis with steroids and aspirin show no preference for either group *Leveaux* (1957) compared the effect of intraarticularly deposited cortisone and procaine in cases of hip osteoarthritis without being able to show any advantage for either substance as regards mobility gait and pain Comparisons have also been made between steroids and local anaesthetics in cases of rheumatoid arthritis and *Fearnley* (1958) could

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MATERIAL AND METHODS

The substances used were 1 prednisolon tertiary butyl acetate and its suspension medium and also 2 methylprednisolon acetate with suspension medium The compositions of these are

1 Prednisolon tert butylacetate 20 mg
Sorbimacropol oleas natr citr trihus
Sorbitol phenylcarbinol et aq steril q s ad 1 ml
(Commercial name Codelcortone TBA MSD)

2 Methylprednisolon acetate 40 mg
Macrogol 4000
4 methyl 1 tetradecylpyridin chl ri l
et natr chlorid q s
Aq steril ad 1 ml
(Commercial name Depomedrone Upjohn)

These preparations as well as the separate suspension media were either

1 applied directly onto the synovial tissue over the bone-cartilage *border in the* exposed knee joint of rabbits or

2 injected into the joint

The amount used ranged from 0 *to 1 5 ml The* experiments were carried out on 14 rabbit knee joints Physiologic saline was injected in 5 *controls*

After urethane anaestesia with intubation the knee joints were carefully opened following microsurgical principles *Before incising the* fibrous capsule and the synovial membrane at its attachment to *the patella all vess ls in the* area of incision were cauterized with *microdiathermy (for* method logical details see *Lindstrom* 1963 1966) Thus a haemorrhage free joint was obtained which left a good view of the intact vessels The *knee joints* were all opened from the lateral aspect as the injections were made from *the medial side* thus leaving the bone cartilage zone and synovial membrane free *from possible* interference by the injection needles As the joint was opened some drops amounting *to about 0 5 to 1 ml* of the media to be examined were applied directly onto the *synovial membrane* Vitalmicroscopic observations were made immediately as well as 15 30 and 120 minutes after the application

In the injection studies readings were *made after 2* hours 6 hours 3 days and 2 weeks The animals were permitted to *run freely* around as soon as they had wakened out of the anaesthesia

The microsurgical procedure was *carried* out under *a Zeiss* operation microscope (x 6 40) The observations were made in incident light with a Leitz Intravital Microscope equipped with an Ultropak *Illuminator* A special apparatus for determinations of corpuscular blood fl w *velocity in* different kinds of vessels was connected to the microscope *(Brån mark & J n son* 1961) By means of a closed circuit TV system with tape-recorder the analyses could easily be repeated *(Brånemark* 1966)

not prove any improvement to the advantage of either preparation. *Chandler et al.* (1958) followed a series of patients with rheumatoid arthritis who received local steroid therapy. On X-ray he found that these patients as compared to a control group during the course of treatment developed an alarming amount of destructive changes in the articular cartilage which was thought to be due to the introduction of the steroid.

Nettelbladt & Sundblad (1963) have studied the effect of steroids on the composition of articular fluid in rheumatoid arthritis. They found that pain was relieved after only a few hours and a decrease of exsudate was seen within the same time. *They believe that steroids stabilise the hyaluronic acid which is incompletely polymerized in states of inflammation. Hyaluronic acid plays an important part in capillary permeability and on its depolymerisation an increase in e. g. protein leakage occurs. On the administration of steroids this capillary permeability decreases due to the stabilising effect of the steroids on hyaluronic acid. Asboe-Hansen (1963) states that steroids inhibit the mast cell activity and so impair capillary permeability.*

McCarthy (1964) on the other hand found that local steroid treatment caused an increase in articular exsudate and that the number of leukocytes was considerably higher.

In a recent study *Brånemark & Goldie* (1966) found that local administration of some steroid compounds in soft tissues causes a complete stop of blood flow in venules. About 90 per cent of the perivascular granular cells were disrupted indicating tissue injury.

After two days the circulation had not been restored but after two weeks the circulation was back to normal in the same vessels as observed before the steroid application.

No reports have been encountered on the effect of steroids on the circulation in synovial tissue. In a previous study (*Brånemark & Goldie* 1966) it was shown that the suspension medium of a locally applied steroid was the causative agent in provoking tissue injury with disturbances in the circulatory conditions. It was therefore thought to be of interest to investigate whether the same observations could be made on articular tissues. If such were the case this might help to explain the adverse effects noted in steroid therapy of joint disease.



Figure 1 Normal capillary loop structure of synovial tissue in rabbit knee joint seen from lateral aspect after opening of the joint Note evenness in structure and shunting capillaries between main branches of loop

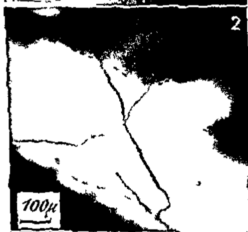


Figure 2 Same area as in Figure 1 after deposition of corticosteroid (Codelcortone) White areas are steroid deposits Note irregularity of vascular structure thinness of vessels interrupted corpuscular continuity and also empty vessels



Figure 3 Same tissue area as Figure 2 but under higher magnification Note same changes as described in Figure 2

RESULTS

1. Action of Direct Local Deposition on Exposed Knee Joint

a) Steroid with Suspension Medium (Codelcortone TBA)

Some difficulties arose in observing the individual vessels as the view was partly obstructed by the milky substance. Registrations could however be made and became easier after a short while when the preparation was dispersed. Immediately after deposition the blood flow was considerably slowed down and the evenness in corpuscular distribution was interrupted by marked plasma skimming. After 30 seconds the blood flow within the area of deposition had stopped in venules as well as in arterioles. The caliber of the vessels seemed to remain the same. No increase in white cells was observed, nor in thrombocytes. No thrombi were seen. The capillary endothelial cells remained normal and no oedema was present. The extravascular structures were normal. On following observations after 15 and 30 minutes the picture remained the same. After 120 minutes a slow corpuscular circulation had commenced in the periphery of the zone of deposition whereas in its centre there was no flow.

After 5 minutes' standstill the area was immersed with physiologic saline. The circulation then started, first with a comparatively slow flow in the most proximal short circuit vessels. Within the next 2 minutes corpuscular flow could be observed even in the most distal part of the capillary loops which are typical for this kind of tissue. When the area was again inundated with the steroid preparation the blood flow came to a stop within 45 seconds. After 10 minutes' application and later it was impossible to regain the circulation with physiologic saline (Figures 1, 2 and 3).

b) Suspension Medium Only (Codelcortone TBA)

In these experiments the vessels were more easily visualized as the substance is more transparent without the steroid component. The observations became a repetition of what had been registered under a). Thus the blood flow stopped within 30 seconds after deposition of the suspension medium and remained so at the reading 2 hours later. The same phenomena with immersion of physiologic saline were repeated.

c) Depomedrone

The same experiments as above were carried out with Depomedrone and its suspension medium. In no instance did this preparation or its

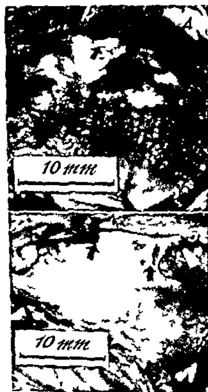


Figure 4 Right rabbit knee joint from the lateral aspect White flocculer masses in the upper subpatellar synovial tissue area 5 days after injection of Codelcortone TBA Slight general oedema of synovial tissue No exaggerated local tissue reaction around cortisone deposit Note unimpaired vessel running across cortisone patch (at arrow)

Figure 5 Right rabbit knee joint from the lateral view 2 weeks after injection of Codelcortone TBA Note lack of reaction around cortisone deposits (at arrows)

vessels was *normal* and the extravascular tissues including granular cells showed no abnormalities (*Figure 5*)

Histology The steroid appeared as an inert amorphous mass surrounded by synovial tissue In no place was the steroid broken up into spread particles but *retained* its compactness There was no cellular reaction of either destructive or reparative type adjacent to the steroid mass (Figures 6 a b c) The cellular layers of the synovial lining did not reveal any abnormal characteristics No oedema was observed

b) *Suspension Medium Only (Codelcortone TBA)*

Macroscopic and vitalmicroscopic All the observations made at the appropriate times after the medium had *been injected* showed exactly the same conditions as were apparent under a) As no differences excepting the white deposits decribed above were present the readings

suspension medium influence the microcirculation in a deleterious way Microcirculatory structure and function remained completely intact when observed at the different intervals

2 Intraarticular Injections

a) Steroid with Suspension Medium (Codelcortone TBA)

Macroscopic and vital microscopic 1 On opening the joints *2 hours* after injection they were filled with a milky floccular mass which was suspended in the synovial fluid The fibrous capsule was normal but the synovial tissue was moderately oedematous The circulation in the vessels of the bone cartilage *zone had stopped whereas in the free part* of the synovium it was intact No increase in white cells or thrombocytes was *noted* The cartilage appeared normal with an even glossy surface The joint was not bulging which was accepted as partial evidence that no greater increase in synovial fluid had occurred

2 After *6 hours* a change of appearance was obvious The fibrous capsule was normal and the synovial membrane was still oedematous but to a much lesser degree The flocculur masses were now dispersed into small granules making the synovial fluid milky like It did not appear increased Some small granules of the *drug* seemed to adhere to both cartilage and synovial tissue Normal circulation was noted in *all types of vessels*

3 After *3 days* the fibrous capsule and the synovium were normal excepting patches of white masses with a cheesy consistency which adhered to the membrane No local reaction was noted around these patches (Figure 4) Vessels in which normal circulation was seen traversed the patches and also surrounded them No signs of increase or budding as an inflammatory response were however noted The fluid appeared normal in colour and consistency Normal circulation was maintained in vessels of all types in the bone cartilage *zone* and *the synovial tissue* The various cell elements were all normal and no increase in thrombocytes or white cells was observed

4 *After 2 weeks the capsule seemed uninterfered with except for the* patches of white "cheese" material which adhered to the synovium and now were somewhat more expansive *The fibrous capsule* was easily detached from the synovial tissue layer including the areas where the deposits were *found* These were now more obviously adherent to the articular cartilage and the fat pads In fact some of them seemed embedded in the fatty tissue The circulation in *all types of*

will not be repeated Further analysis showed that one component sorbitol caused the vascular reaction

Histology In the light microscope there were no signs of cellular or vascular reactions

c) *Depomedrone* disclosed no changes as described under a and b

d) *Physiologic Saline*

Macroscopic and vitalmicroscopic The controls in which physiologic saline was injected disclosed no abnormalities irrespective of time lag between injection and recording

The histologic picture also remained normal

COMMENTS AND CONCLUSION

It is generally accepted that the therapeutic value of steroid compounds in joint disorders is great but of late a certain resistance to their use has become prevalent They are however still widely used despite the disadvantages their local application seem to cause As previously mentioned *Chandler et al* (1958) ascribed cartilage defects and de structions as they appeared on X ray in cases of rheumatoid arthritis to the use of intraarticular steroids This idea has been challenged by *Edstrom* (1961) who was of the opinion that the process of rheumatoid arthritis is such as to produce destructions of the kind described by *Chandler et al* If however it is true that the use of cortisone may provoke cartilage destructions it could partly be explained by the observa tions of *McCarthy* (1964) who found a richness in leukocytes in articu lar exsudate These cells produce a proteolytic enzyme which influences the chondromucoproteins in a way as to cause destruction of cartilage Thus steroids indirectly via the leukocytes would give rise to cartilage damage On the other hand the investigation by *Nettelbladt & Sundblad* (1963) indicates that there is no increase in the exsudate of a diseased joint treated with cortisone

In view of this it was thought of interest to investigate the influence of intraarticularly administered cortisone in normal joints and especi ally the vascular reaction As it was known from previous investiga tions on soft tissues that steroid preparations cause microcirculatory disturbances (*Brånemark & Goldie* 1965) and that this in turn is due to the suspension medium this investigation aimed at finding out if the joint vascular bed reacted in the same way



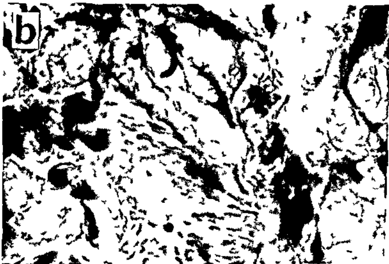




Figure 6. Histologic sections of local deposit of cortisone in synovial tissue. No apparent surrounding tissue reaction.

a) general view (× 75)

b) venule with a few surrounding round cells (× 400)

c) border zone between steroid and connective *tissue* (× 600)

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The circulation in the synovial tissue and bone cartilage zone reacted with a stop in circulation exactly similar to that of soft tissues and the standstill in blood flow was due to the suspension medium used containing sorbitol (Codelcortone TBA) No such changes were however observed with Depomedrone the suspension medium of which contains microgol with a lower molecular weight As for cellular damage the perivascular cells were disrupted

It is interesting to note that the deposition of cortisone in synovial tissue and the lack of its resorption do not cause any cellular or other changes as observed by light microscopy In 1964 (*Goldie*) carried out a study on the pathogenesis of tennis elbow In a number of cases a similar phenomenon as described above was observed with floccular masses of steroid deposited in the soft tissues surrounding the epicondyle The time during which these *depositions had lodged in the* soft tissues varied from 1 to 3 years without any obvious interference with cellular structure but above all which is just as important without any cure of the disease *No analysis was made of the floccular sub*stance but it would no doubt be interesting to find out if this contained any unabsorbed corisone or suspension medium If this were the case *how then does locally applied cortisone act—and for how long a time?* Investigations have been instituted to further explore these problems

The cause of cessation of blood flow is probably to be found in a direct damage to the exposed tissues including the vascular wall The frequent finding of disrupted perivascular granular cell verifies this theory as such a mechanism is also an early sign of tissue injury

It is important to point out that these observations were made on normal tissues What bearing they have on already damaged tissues with for example inflammatory changes remains to be investigated It is however *known from other studies that tissues which have already been* damaged to some extent and thus exhibit signs of tissue injury have a lower threshold level for additional injury Thus it appears reasonable to assume that if cortisone preparations of the kind tested here are applied to tissues affected by rheumatoid disease *e g* the tissue would react with changes of at least the same magnitude as normal tissue and most probably with even more pronounced disturbances in tissue structure and function

SUMMARY

The use of corticosteroids in joint disease is controversial Cartilage damage and soft tissue reactions have been ascribed to these agents

A study was carried out in normal rabbit knee joints to clarify the action of locally administered steroids and a comparison was made between two usual commercial preparations. It was found that one of them (Codelcortone TBA) had a damaging influence on the synovial microcirculation in that it caused an arrest in the nutritive flow of blood. Perivascular granular cells were disrupted. On further analysis of this preparation it was found that a component, sorbitol, of the suspension medium caused the microcirculatory disturbances.

The other preparation used (Depomedrone) did not cause any such damage.

RESUME

L'utilisation de corticosteroides dans les maladies des articulations est controversable. Des dommages cartilagineux et des reactions des tissus mous ont ete attribues a ces agents.

Une etude a éte pratiquée sur des articulations normales du genou de lapins afin de clarifier l'action des steroides administres localement et une comparaison a éte faite entre deux preparations courantes dans le commerce. Il a ete trouve que l'une d'elles (codelcortone TBA) avait une influence prejudiciable sur la microcirculation synoviale en causant un arret du courant nutritif de sang. Des cellules granulaires perivasculaires avaient éclaté. Une analyse plus approfondie de la preparation a dévoilé que c'est un composant, le sorbitol, dans le milieu de suspension qui cause les troubles microcirculatoires.

L'autre preparation utilisee (Depomedrone) n'a a cause aucun dommage de ce genre.

ZUSAMMENFASSUNG

Die Verwendung von Cortico-steroiden bei Gelenkkrankheiten ist umstritten. Knorpelbeschadigung und Reaktionen der Weichteile sind diesen Agenden zugeschrieben worden. Um die Wirkung von lokal administrierten Steroiden zu untersuchen, ist ein Studium normaler Kniegelenke vom Kaninchen gemacht worden nebst einem Vergleich zweier allgemein verwendeter kommersieller Praparate.

Es wurde gefunden dass das eine ihnen (Cordelcorton T.B.A.) eine schadliche Einwirkung auf die synoviale Mikrozirkulation hatte, indem eine Verlangsamung der nutritiven Durchblutung verursacht wurde. Perivasculare granulierte Zellen wurden gesprengt. Durch fortgesetzte Analyse dieses Praparates wurde gefunden, dass Sorbitol—eine kom

The circulation in the synovial tissue and bone-cartilage zone reacted with a stop in circulation exactly similar to that of soft tissues and the standstill in blood flow was due to the suspension medium used containing sorbitol (Codelcortone TBA). No such changes were, however, observed with Depomedrone, the suspension medium of which contains macrogol with a lower molecular weight. As for cellular damage, the perivascular cells were disrupted.

It is interesting to note that the deposition of cortisone in synovial tissue and the lack of its resorption do not cause any cellular or other changes as observed by light microscopy. In 1964 (Goldie) carried out a study on the pathogenesis of tennis elbow. In a number of cases a similar phenomenon as described above was observed with floccular masses of steroid deposited in the soft tissues surrounding the epicondyle. The time during which these depositions had lodged in the soft tissues varied from 1 to 3 years without any obvious interference with cellular structure but, above all, which is just as important, without any cure of the disease. No analysis was made of the flocculated substance but it would no doubt be interesting to find out if this contained any unabsorbed corisone or suspension medium. If this were the case, how then does locally applied cortisone act — and for how long a time? Investigations have been instituted to further explore these problems.

The cause of cessation of blood flow is probably to be found in a direct damage to the exposed tissues including the vascular wall. The frequent finding of disrupted perivascular granular cell verifies this theory as such a mechanism is also an early sign of tissue injury.

It is important to point out that these observations were made on normal tissues. What bearing they have in already damaged tissues with for example inflammatory changes remains to be investigated. It is, however, known from other studies that tissues which have already been damaged to some extent and thus exhibit signs of tissue injury have a lower threshold level for additional injury. Thus it appears reasonable to assume that if cortisone preparations of the kind tested here are applied to tissues affected by rheumatoid disease, e.g., the tissue would react with changes of at least the same magnitude as normal tissue and most probably with even more pronounced disturbances in tissue structure and function.

SUMMARY

The use of corticosteroids in joint disease is controversial. Cartilage damage and soft tissue reactions have been ascribed to these agents

A study was carried out in normal rabbit knee joints to clarify the action of locally administered steroids and a comparison was made between two usual commercial preparations. It was found that one of them (Codelcortone TBA) had a damaging influence on the synovial microcirculation in that it caused an arrest in the nutritive flow of blood. Perivascular granular cells were disrupted. On further analysis of this preparation it was found that a component, sorbitol, of the suspension medium caused the microcirculatory disturbances.

The other preparation used (Depomedrone) did not cause any such damage.

RESUME

L'utilisation de corticosteroïdes dans les maladies des articulations est controversable. Des dommages cartilagineux et des reactions des tissus mous ont ete attribues a ces agents.

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L'autre preparation utilisee (Depomedrone) n'a a cause aucun dommage de ce genre.

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Die Verwendung von Cortico steroiden bei Gelenkkrankheiten ist umstritten. Knorpelbeschädigung und Reaktionen der Weichteile sind diesen Agenden zugeschrieben worden. Um die Wirkung von lokal administrierten Steroiden zu untersuchen, ist ein Studium normaler Kniegelenke vom Kaninchen gemacht worden, nebst einem Vergleich zweier allgemein verwendeter kommersieller Praparate.

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ponente des Suspensionsmediums—die microzirkulatorischen Störungen verursachte.

Das andere der verwendeten Präparate (Depomedrone) verursachte keine derartigen Schäden.

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(Head Professor A Langenskiold M D)

THE DEVELOPMENT OF MULTIPLE CARTILAGINOUS EXOSTOSES

By

A LANGENSKIOLD

Received 8 III 67

In two articles published in 1947 and 1949 (*Langenskiold & Edgren*) the present author discussed the pathogenesis of multiple cartilaginous exostoses on the basis of clinical radiological studies and of experiments concerning bone growth after X ray injury to localized portions of epiphyseal plates

It seems clear that the pathogenesis of cartilaginous exostoses can not be understood without knowledge of the course of the normal histogenesis in the transition zone between the epiphyseal plate and the osteogenic layer of the diaphyseal periosteum This zone has been called the ossification groove (encoche d ossification) of Ranvier The origin of the cells of the ossification groove and the question of how the epiphyseal cartilage grows in diameter are still subject to discussion in the literature (*Rigal Solomon Langenskiold Rytomaa & Vademan*) Furthermore as very few authors interested in the pathogenesis of cartilaginous exostoses have had an opportunity to follow the development of exostoses in their early stages by repeated radiographs the pathogenesis of this hereditary disease is still considered obscure

On the basis of observations reported in 1947 and 1949 the present author assumed that cartilaginous exostoses may arise in the following way limited portions of the undifferentiated cell layer which is displaced by growth from the interior of the epiphyseal cartilage to the surface of the bone do not as would normally be the case give rise to cells of an osteoblastic nature These pathological portions of tissue retain their chondrogenic properties giving rise to a cartilaginous layer on the surface of the bone which forms the outermost zone of the

ponente des Suspensionsmediums—die microzirkulatorischen Storungen verursachte

Das andere der verwendeten Praparate (Depomedrone) verursachte keine derartigen Schaden

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Figure 2 Radiograph of the same knees as seen in Figure 1 Age six years

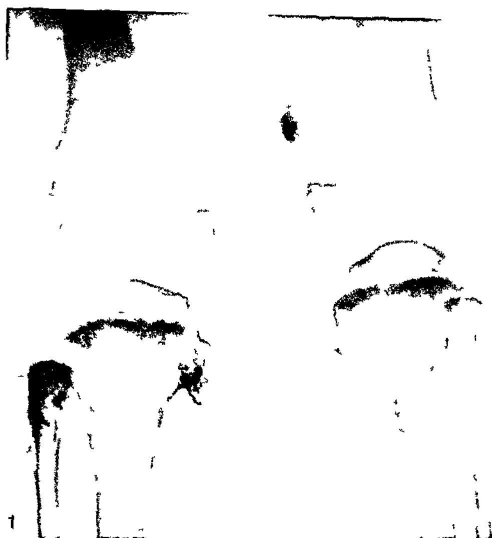


Figure 1 Radiograph of the knees of a child with multiple cartilaginous exostoses Age four years

exostosis Owing to this local disturbance of the differentiation of cells the formation of an osteogenic layer fails to occur in the corresponding places as also do the processes which are dependent on such an osteogenic layer the formation of periosteal bone and tubulation and modelling of bone

A thorough search in 1946 and 1947 of the literature and of the archives of radiological departments of the university hospitals in Helsinki and Stockholm did not give a possibility to judge from serial radiographs the course of the development of cartilaginous exostoses In 1950 *Lacroix* showed that the place of attachment of a pedunculated exostosis to the bone is displaced by remodelling towards the



Figure 2 R ograph of the same knees as seen in Figure 1 Age six years



Figure 3. Picture published by A. Langenskiöld in 1947. Schematic drawing illustrating the development of multiple cartilaginous exostoses (three stages).

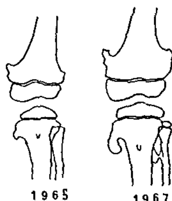


Figure 4. Contour drawings of the left knee region as seen in the radiographs of Figures 1 and 2. To the left 1965, to the right 1967.

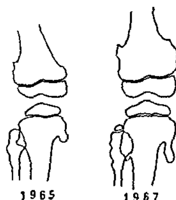
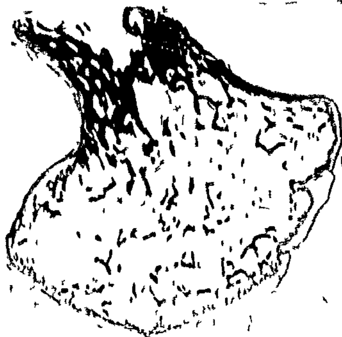


Figure 5. Contour drawings of the right knee region as seen in the radiographs of Figures 1 and 2. To the left 1965, to the right 1967.

end of the bone with its continued growth. However, serial radiographs illustrating the early stages of development of pedunculated exostoses have not been seen by the present author in the literature. The publication of radiographs of a young child (Figures 1 and 2) showing the development of small cartilaginous exostoses situated close to the epiphyseal cartilages into large pedunculated or broadbased exostoses within two years seems therefore justified.

Figure 3 shows a schematic drawing published by the present author in 1947. The drawing illustrating three stages of development of cartilaginous exostoses was drawn on the basis of radiographs showing different exostoses at different stages of development. The observations made in 1947 are now completed by the radiographs seen in Figures 1 and 2. Figure 4 shows contour drawings of the radiographs of the left knee region in 1965 and 1967 (Figures 1 and 2) and Figure 5 the corresponding drawings of the right knee region. Figure 6 shows



6

Figure 6 Photomicrograph of a section taken in the frontal plane of the pedunculated exostosis of the left tibia seen in Figure 2 The exostosis was removed soon after the radiograph had been taken The top of the exostosis (at the bottom of the picture) is covered by a layer of cartilage

a microscopical section of the top of the pedunculated exostosis of the left tibia as seen in Figure 2

In the literature there is a microphotograph of a cartilaginous exostosis in an early stage of development which is probably unique (Figure 7) Leveuf (1936) took a biopsy of a cartilaginous exostosis of a growing child and included in the same section the adjacent part of the epiphyseal plate and a portion of the bony epiphysis (Figure 7 *A*) In Figure 7 *B* the topography of the cartilaginous layer covering the exostosis in relation to the epiphyseal cartilage and to the ossification groove is clearly seen This exostosis is in a similar stage of development as the exostosis of the left tibia seen in Figure 1 This would mean that Figure 6 would correspond to a later stage of development of an exostosis similar to that illustrated by Figure 7 *B*

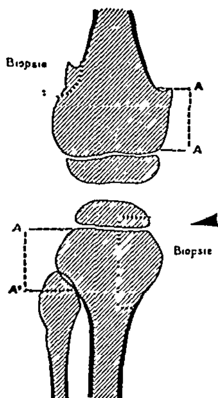
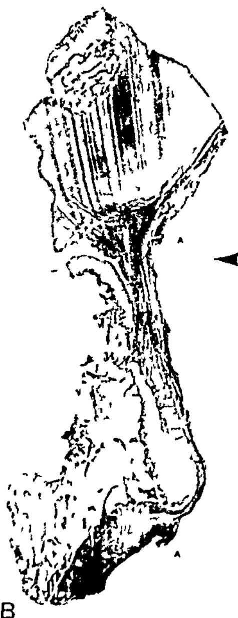


Figure 7 A



7B

Figure 7. A and B are both pictures published by Leveuf in 19[illegible]. A. A contour drawing of the knee region of a child with multiple cartilaginous exostoses aged seven years. For biopsy a section was taken from the tibia in the frontal plane. The section included the exostosis, the peripheral part of the epiphyseal plate and a part of the epiphyseal nucleus. B. Microphotograph of the section described under A. The cartilaginous layer covering the exostosis and the epiphyseal plate merge, as do the perichondrium covering the cartilaginous layer and the tissue of the ossification groove ("encoche d'ossification").

Today the possibilities of differentiation of the different kinds of cells occurring in the skeleton are better known than in 1947 *Holtrop* stated in 1966 that cartilage cells may differentiate into connective tissue (perichondrium or periosteum) and then form bone afterwards She concluded that to the list of possible precursors of bone cells the cartilage cell should be added This means that the existence of a layer of undifferentiated connective cells in the epiphyseal plate is not a prerequisite for understanding the conception of the pathogenesis of cartilaginous exostoses held by the present author

SUMMARY

In a child with multiple cartilaginous exostoses the development of small exostoses in the neighbourhood of the epiphyseal cartilages at the age of four years into large pedunculated or broad based exostoses at the age of six years could be followed by radiography The observation is in accordance with findings reported by the author in 1947 and 1949

RESUME

Chez un enfant ayant de multiples exostoses cartilagineuses le developpement de petites exostoses dans la proximite des cartilages epiphysaires a l age de 4 ans en grandes exostoses pedonculaires ou a large base a l age de 6 ans a pu etre suivi sur des radiographies l observation concorde avec les trouvailles rapportees par l auteur en 1947 et 1949

ZUSAMMENFASSUNG

Bei einem Kind mit multiplen kartilaginaren Exostosen konnte die Entwicklung von kleinen in der Nahe vom Epiphysenknorpel gelegenen Exostosen im Alter von vier Jahren zu grossen gestielten und breitbasigen Exostosen im Alter von sechs Jahren roentgenologisch gefolgt werden

Die Observation bestatigt vom Verfasser im Jahre 1947 veroffentlichte Befunde

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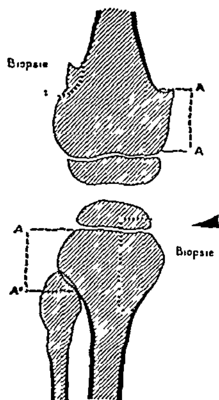


Figure 7 A



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From the Hospital of the Invalid Foundation Helsinki Finland
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THE POSSIBILITIES OF ELIMINATING PREMATURE PARTIAL CLOSURE OF AN EPIPHYSEAL PLATE CAUSED BY TRAUMA OR DISEASE

By

A LANGENSKIOLD

Received 26 i 67

The phenomenon of a traumatic defect in an epiphyseal plate being filled out by bone tissue if there is simultaneous mechanical injury to both adjacent metaphyseal and epiphyseal bone was described by *Nove Josserand* in 1894 The clinical importance of the post traumatic formation of bony bridges between the epiphysis and the metaphysis in a tubular bone in a growing child is today well established

In 1933 *Phemister* described his method for the operative arrestment of longitudinal growth of bones This method implies that the area of fusion of the epiphysis and the metaphysis is large enough to arrest growth completely in the epiphyseal cartilage in question Among others *Abbot & Gill* (1942) and *Aitken & Magill* (1952) have described deformities resulting from post traumatic partial closure of the epiphyseal plate in the distal end of the femur *Salter & Harris* wrote in 1963 (p 612) "After an epiphyseal plate injury local growth may either cease immediately or it may continue at a retarded rate for a variable period before complete cessation Furthermore *the growth* disturbance may involve either the entire epiphyseal plate or only one part of it The resultant deformity is *progressive* until the end of the child s growing period

Concerning the prognosis of a traumatic deformity caused by a bony bridge formed between an epiphysis and a metaphysis in a growing bone the present author did not know of any definite exceptions from the rule formulated by *Salter & Harris* before the Case 1 described below was seen

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Figure 2 Case 1 A and B Radiographs of the right knee Age ten years

follow-up ... months but a gradual disappearance of the epiphyseo metaphyseal bony bridge up to August 29 1959 *the right femur* had grown more than two centimeters from the distal end (Figure 5) The extremity *was straight* and there was no sign of partial closure of the right distal femoral epiphyseal cartilage (Figure 4) The right femur was one and a half centimeter shorter *than the left* There was no recurrence of the deformity and when growth was finished the right femur was one centimeter shorter *than the left* and had grown about eight centimeters from the distal end after the osteotomy (Figure 6)

The case described above showed that *spontaneous* release of the growth impeding effect from a bony bridge between an epiphysis and a metaphysis can occur *even when it* has caused a deformity requiring operative treatment In 1963 *Blount after having* seen the radiographs recommended that a report of this case should be *written* The case

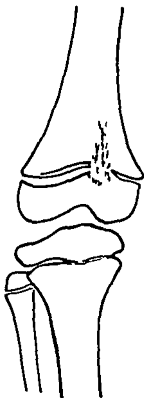


Figure 1 Case 1 Age ten years Contour drawing of antero posterior radiograph of the right knee Note the bony bridge between the distal epiphysis and the metaphysis of the femur causing progressing varus and recurvatum deformity

Case 1 H N a boy born February 20 1946 After a trauma to the right knee region in 1954 the boy was limping X ray examination several months after the injury gave a negative result When the boy was seen for the first time by the present author on May 19 1956 there was marked recurvatum and varus deformity *in the right knee region X ray examination showed a bony bridge between the* metaphysis and the epiphysis in the antero medial part of the distal end of the femur (Figure 1)

In August 1956 the right knee could be hyperextended fifteen degrees more than the left and there were ten to fifteen degrees of varus deformity The deformity was localized to the distal epiphyseal region of the right femur (Figures 2 and 3) The presence of a bony bridge between the metaphysis and the epiphysis was verified The right femur was three centimeters shorter than the left

On August 23 1956 a supracondylar osteotomy of the right femur was performed and the deformity was corrected with slight overcorrection of the varus The osteotomy consolidated in less than two months (Figure 3) The zone of partial epiphyseal closure of the distal femoral epiphysis was still visible in the radiograph

On the basis of general experience from similar cases the parents were told that recurrence *of the deformity would probably occur and repeated osteotomy* would be necessary Repeated X ray examinations showed no recurrence of the

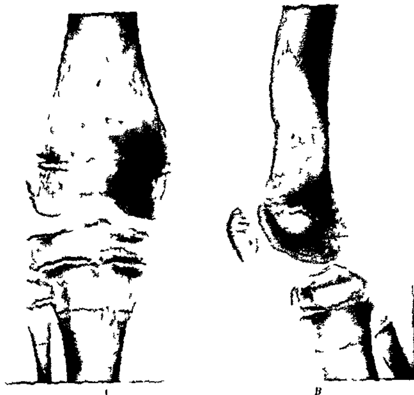


Figure 3 Cas 1 A Anter p sterior radiograph of the r ght knee two years an l f ur months after osteot my B Si le view ra liograph of the right knee two years after osteot my Th b y bri lg connect g the epiphysis and the m taphysis of the femur could no l nger be seen

also seemed to suggest the possibility of the restitution of normal growth in similar cases if an adequate operative method for eliminating epiphyseal closure in circumscribed areas could be found In case 2 removal of a bony bridge between the epiphysis and the metaphysis in the upper end of the tibia was *followed* by a definite reduction of deformity by growth

Case 3 A b y a l y born May 13 19 0 In March 1965 a deformity of the right knee wa noticel There was *no history of* trauma or severe illness An older b ther of the patient ha l a similar deformity in *one* knee

At a clinical examinati n *in June* 196 it was found that the right knee could be hyperextended t enty degrees more th n the left X ra examination revealed a marked recurvatum deformity in the upper end of the right tibia (Figure 7)

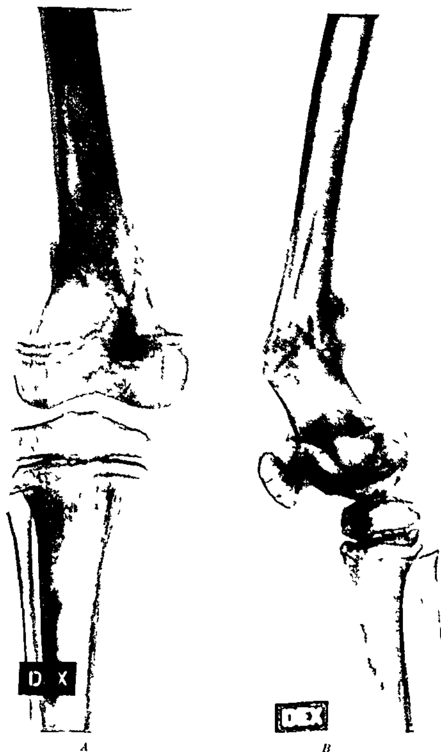


Figure 3. Case 1. Age ten years and nine months. Radiographs of the right knee region two and a half months after supracondylar osteotomy of the femur and correction of the deformity. A. Antero-posterior view. B. Side view.

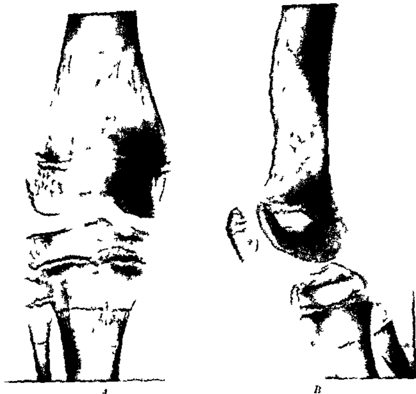


Figure 6 Case 1 A Antero posterior radiograph of the right knee two years and four months after osteotomy B Side view radiograph of the right knee two years after osteotomy The bony bridge connecting the epiphysis and the metaphysis of the femur could no longer be seen

also seemed to suggest the possibility of the restitution of normal growth in similar cases if an adequate operative method for eliminating epiphyseal closure in circumscribed areas could be found In case 2 removal of a bony bridge between the epiphysis and the metaphysis in the upper end of the tibia was followed by a definite reduction of deformity by growth

Case 2 A K a boy born May 13 1950 In March 1955 a deformity of the right knee was noticed There was no history of trauma or severe illness An older brother of the patient had a similar deformity in one knee

At a clinical examination in June 1955 it was found that the right knee could be hyperextended twenty degrees more than the left X ray examination revealed a marked recurvatum deformity in the upper end of the right tibia (Figure 7)

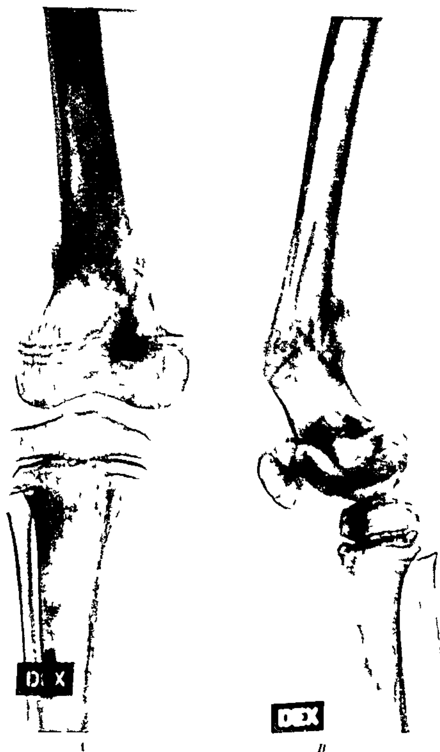


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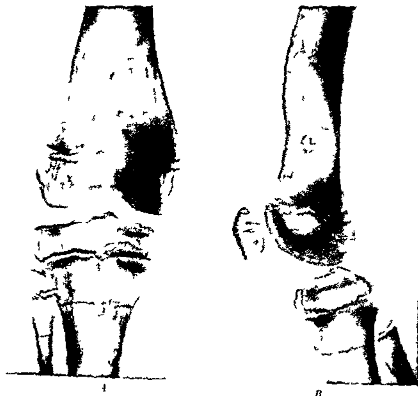


Figure 4 Case 1 A Antero posterior radiograph of the right knee two years and four months after osteotomy B Side view radiograph of the right knee two years after osteotomy The bony bridge connecting the epiphysis and the metaphysis of the femur could no longer be seen

also seemed to suggest the possibility of the restitution of normal growth in similar cases if an adequate operative method for eliminating epiphyseal closure in circumscribed areas could be found In case 2 removal of a bony bridge between the epiphysis and the metaphysis in the upper end of the tibia was followed by a definite reduction of deformity by growth

Case 4 A K a boy born May 13 19[illegible]0 *In March* 196[illegible] a deformity of the right knee was noticed *There* was no history of trauma or severe illness An older brother of the patient had *a similar* deformity in one knee

At a clinical examination *in June* 196[illegible] it was found that the right knee could be hyperextended twenty degrees more than the left X-r[illegible] examination revealed a marked recurvatum *deformity* in the upper end of the right tibia (Figure 7)



Figure 5. Case 1. Contour drawings of Figure 3 B and Figure 4 B showing normal growth of the lower end of the right femur in two years following osteotomy.

The distal end of the anterior portion of the proximal tibial epiphysis was found to be fused to the metaphysis (Figure 8).

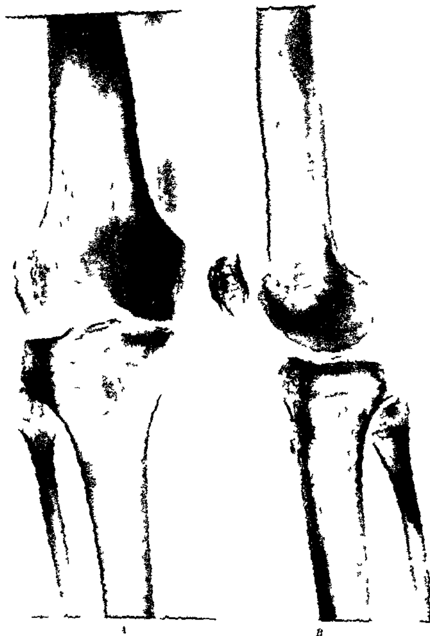
As the patient's skeletal age was fourteen, or one year retarded, it was decided to try to resect the epiphyseo-metaphyseal bony bridge in order to eliminate the local growth-impeding factor producing progressive deformity.

On June 10, 1965 the proximal part of the beak-like anterior part of the upper tibial epiphysis was resected proximal to the insertion of the patellar tendon. It was controlled by direct vision that the bony connection between the epiphysis and the metaphysis was eliminated. The space occupied by the resected piece of bone was filled by free transplants of subcutaneous and infrapatellar fat tissue.

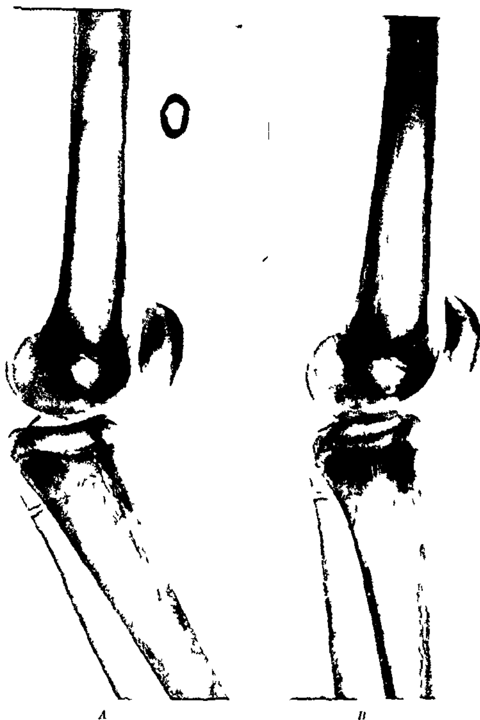
Two and a half months after the operation, tomography showed no reformation of a bony bridge between the epiphysis and the metaphysis (Figure 10). The recurvatum deformity gradually diminished. On November 15, 1966 the epiphyseal cartilages of the extremities were found to be closing. The recurvatum deformity of the right knee had diminished by about ten degrees and was no longer apparent enough to attract the attention of the patient or his parents (Figures 9 and 11).

DISCUSSION

There have been two ways of dealing with progressive deformities caused by partial closure of an epiphyseal plate. Repeated osteotomies with over-correction to delay the time of recurrence has been the



F gu 6 Case 1 A and B The ... knee region at the age of nineteen y ars



A B

Figure [illegible]. Case 2. Age fifteen years. Skeletal age fourteen years. Side-view radiographs of both knees in maximal hyperextension. Recurvatum deformity in the upper end of the right tibia. A, Right leg. B, Left leg.



Figure 8 Case 9 Age fifteen years A Plain radiograph taken tangentially to the bony bridge connecting the anterior part of the upper tibial epiphysis with the metaphysis B Tomograph corresponding to A

method of choice in young children and when the important distal end of the femur is concerned In children over nine years of age epiphyseodesis of the growing part of the damaged epiphyseal plate has proved adequate in the upper end of the tibia (*Langenskiold & Riska*)

The great risk of causing additional damage to an epiphyseal cartilage or to its blood supply has probably prevented most orthopaedic surgeons from trying to restore normal growth in partially closed growth zones However some experimental work (*Johnson & Southwick Friedenberg Key & Ford*) and the cases described above suggest that operative elimination of premature closure of a circumscribed area of an epiphyseal cartilage could be possible In 1949 *Langenskiold & Edgren* showed that X ray injury to limited portions of an epiphyseal plate did not provoke partial closure of the plate Apparently the injured portion of cartilage prevented fusion of the epiphysis to the metaphysis

The type of recurvatum deformity caused by partial closure in the anterior part of the tibia was extensively reviewed by *Pellesohn* in 1933 In recent years cases have been described by *Stirling* (1952) *Kellock* (1958) *Fielding Liebler & Tambakis* (1960) and *Morton & Starr* (1964) In this group of cases the closure of the plate appears close to the periphery and is thus easily approachable by surgical intervention In case 2 described above implantation of fat prevented the reformation of the bony bridge for a long enough time to allow correction of the deformity by growth According to the experiments of



Figure 9. Case 2. Age sixteen and a half years. Side view in maximal hyperextension of the right knee region one year and five months after resection of the bony bridge impeding growth in the anterior part of the upper tibial epiphyseal plate. The recurvatum deformity had diminished by about ten degrees (compare with Figure 7-A). Four other side-view radiographs taken in slightly different projections with the X-ray tube situated slightly anteriorly and posteriorly compared to Figure 7-A and Figure 9 showed variations of recurvatum within two degrees.



Figure 10

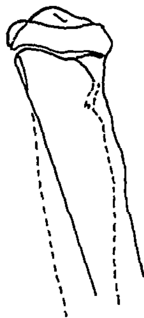


Figure 11

Figure 10 Case Side view tomograph of the upper end of the tibia two and a half months after operation No signs of reformation of the bony bridge (compare with Figure 8 B)

Figure 11 Case 2 Contour drawings of the upper end of the tibia as seen in Figure 7 A and Figure 9

Langenskiold & Edgren and to those of *Heikel* concerning epiphyseal transplantation dead cartilage might be another material suitable for interposition between the epiphysis and the metaphysis Whether bony bridges in the inner parts of an epiphyseal plate would be accessible by surgical intervention from the side of the metaphysis without provoking additional growth disturbing factors is a question which needs further experimental research

SUMMARY

In a boy aged ten and a half years partial closure had appeared in the antero-medial part of the distal epiphyseal plate of the femur

within two years after trauma. Recurvatum and varus deformity of the knee and a three centimeter shortening of the affected bone were present. After supracondylar osteotomy and correction of the deformity the bony bridge disappeared and the bone grew normally until maturity.

In another boy resection of a bony bridge between the anterior part of the upper tibial epiphysis and the metaphysis at the skeletal age of fourteen years led to a ten degree correction by growth before maturity.

There seem to be possibilities of creating operative methods for the elimination of epiphyseal closure in circumscribed areas.

RÉSUMÉ

Chez un garçon âgé de 10 ans et demi une fermeture partielle de la partie antéro-médiane de la plaque épiphysaire du fémur s'est manifestée dans les deux ans qui ont suivi un trauma. La déformation en recurvatum et varus du genou et un raccourcissement de 3 cm de l'os ont été constatés. Après ostéotomie supracondylaire et correction de la déformité le pont osseux disparut et la croissance de l'os s'effectua normalement jusqu'à maturité.

Chez un autre garçon la résection d'un pont osseux entre la partie antérieure de l'épiphyse tibiale supérieure et la métaphyse à l'âge de 14 ans a abouti à une correction de dix degrés par la croissance avant maturité.

Il semble qu'il soit possible de trouver des méthodes opératoires pour empêcher la fermeture épiphysaire dans des parties circonscrites.

ZUSAMMENFASSUNG

Bei einem Knaben im Alter von zehn und ein halb Jahren fand eine partielle Schliessung im antero-lateralen Teil der distal Epiphysenfuge des Femurs statt innerhalb zwei Jahren nach einem Trauma. Eine Recurvatum- und Varusdeformität des Knies und eine Verkürzung von drei centimetern wurden festgestellt. Nach einer suprakondylären Osteotomie und Korrektion der Deformität verschwand die knöcherne Brücke und das Femur ist normal gewachsen bis zur Maturität.

Bei einem anderen Knaben leitete eine Resektion einer knöchernen Brücke zwischen dem vorderen Teil des Epiphysenkerns und der Metaphyse des oberen Endes der Tibia im Alter von vierzehn Jahren

zu einer Korrektion einer Recurvatumdeformität vor dem Ende des Wachstums

Es scheint als ob es Möglichkeiten gäbe operative Methoden zu entwickeln mit denen ein vorzeitiger Schluss eines begrenzten Gebietes einer Epiphysenfuge eliminiert werden kann

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Figure 1



Figure 2

Figure 1 Radiograph in 19 9 when the patient was five years old The right femur is slender the left thickened The hip joints appear normal

Figure 2 Radiograph in 1962 after bilateral release operation for hip contracture There is a considerable callus f rmation at the lateral border of the left acetabular roof

units/ml The condition w s interpreted as a streptococcal infection (AST ?300) and the symptoms gradually subsided under antibiotic treatment A rad ogram two months after the operations showed considerable callus formation in the area f the left hip and sl ght callus formati n above the right hip joint (Figure 2) Continuous therapy with anabolic hormone was instituted (dianabol 1 mg×3) d sage periods of two weeks alternating with intervals of two weeks

Nine months later in February 1963 the patient was readmitted He had had fe er for two weeks and progres ive swelling of the left thigh Remitting diagnosis ost myelitis femo is sin The left thigh was swollen and hot and the skin reddish w th dilated veins The clinical appe rance is seen in Figure 3

S dimentation rate 4? Hb 9 7 g Alkaline phosphatases 5 Bodansky units One month later the phosphatase value had risen to 13 Radiogram (April 5 1963) (Figure 5) sho ved slight callus formation and extensive infiltration of the soft tissues of the left femur but no fracture Since cl nically and rad ologically there w s a suspicion of sarcoma biopsy was carried out on April 16 1963 Microscopic xamination howed undeveloped cartilage cells which did not form an organized structure The cells were in places spindle shaped resembling myxoma cells The stroma was loose No mitoses Histologically the tumour was benign PAD Chon dro myxo fibroma (Figure 4)

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From the Orthopaedic Hospital of the Invalid Foundation
(Head: Professor A. Langenskiöld, M.D.), Helsinki, Finland

HYPERPLASTIC CALLUS FORMATION IN OSTEOGENESIS IMPERFECTA

Report of a case simulating sarcoma

By

L. E. Laurent & P. Salenius

Received 27 ii 67

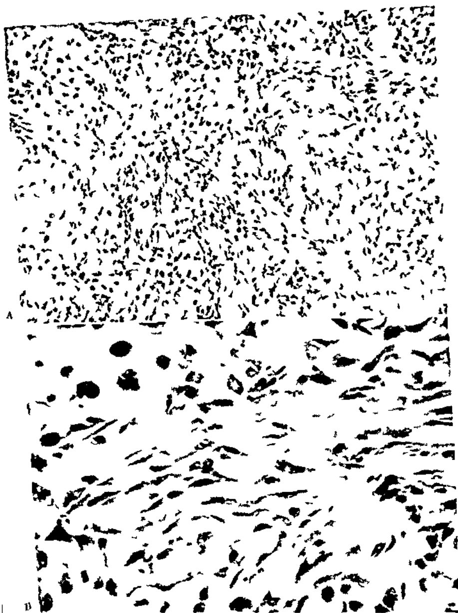
Hyperplastic callus formation in osteogenesis imperfecta is rare. *Strach* (1953) stated that fifteen cases had been described in the literature. The pathology was described by *Baker* (1946) and the clinical picture by *Fairbank & Baker* (1948). Early in the course of the disease particularly, the clinical picture and the radiological findings resemble those of sarcoma. At least two cases have been described in the literature in which amputation was carried out, but the subsequent course showed that the condition had been due to hyperplastic callus formation. We therefore feel justified in reporting a further case.

CASE REPORT

The boy, born in 1954, was first seen at the age of three years. There was a history of fracture of the right femur at birth. Later there had been fractures of the ribs and the right tibia. No family history. The patient had not blue sclerae. No gross deformities; the patient was able to walk. In 1959 the radiograms showed typical platyspondylia with codfish vertebrae; there were fractures of the left tibia and the right fibula. The right femur was very slender. There was thickening of the distal part of the left femur (Figure 1). The patient was no longer able to walk.

In 1962 the patient was admitted to the hospital. During the preceding year he had fractured both tibiae. Severe antecurvatum and valgus deformity of both legs had developed. The spine was kyphotic and the thorax deformed. The upper extremities looked almost normal. In both hips there was severe flexion contracture. A two stage release operation with fasciotomy at the anterosuperior iliac spine was carried out on both sides.

Two weeks after the last operation the patient had fever lasting for two months. The sedimentation rate rose to 65 and the Hb fell to 9.1 g. The calcium and phosphorus values were normal, and the alkaline phosphatase rose to 13 Bodansky



F g ir 4 A an l B Mi rographs f se ti n of biopsy specimen of the callus tumou taken it 4 1JCJ Nu l ar pleom rphism an l hyp rchromasia a e seen in tissue con taining fib blasts and honde ytes (A × 80 B × 267 IIF)

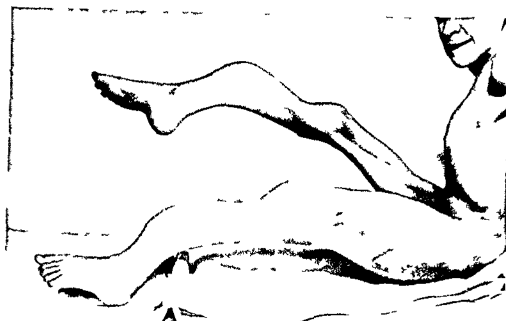


Figure 3. The appearance of the patient on 4.4.1963 when a callus tumour had developed in the left thigh which was swollen, reddish and hot. Severe antecurvatum deformity of both tibiae.

The patient was sent to another hospital for radiotherapy. For a period of three weeks he was given 2300 r into the tumour and there was evident regression. Biopsy was again carried out on May 11, 1963, four weeks after the earlier biopsy, four different pathologists being consulted. At this stage the patho-anatomical diagnosis was callus tissue. Radiogram of June 14, 1963 shows hyperplastic callus (Figure 6). The condition normalized about one month later, although there was still considerable thickness of the proximal part of the left femur.

The patient returned to the hospital 3½ years later in December 1966. He had been to a school for crippled children since autumn 1963, sitting in a wheel-chair. There was severe deformity of the lower extremities. Both tibiae were sabre-shaped. There was marked flexion contracture in the hip and knee joints. Mobility in the hip joints was insignificant and in the knee joints very limited. As a result of platyspondylia there was a marked gibbus and the chest was sagittally compressed. The cranial bones were thin but otherwise the head was normal and the teeth good. There were no significant deformities in the upper extremities and their function was satisfactory. Radiograms of the forearms showed bilateral bony exerescences on the interosseous border of radius and ulna. The patient had had no fractures since 1962, since when anabolic hormone had been continuously administered.

For the past month the patient had had pain in his right thigh in which a diffuse induration could be felt. The sedimentation rate was increased, 33, but there were no other inflammatory symptoms. The left femur was proximally thickened as

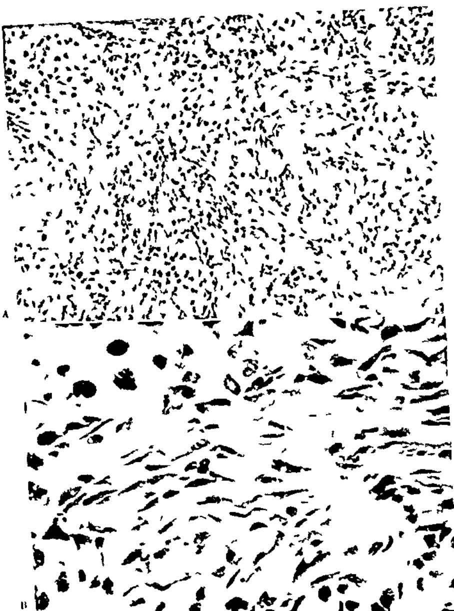


Figure 4 A and B Micrographs of section of biopsy specimen of the callus tumour taken 16 4 1963 Nuclear pleomorphism and hyperchromasia are seen in tissue containing fibroblasts and chondrocytes (A × 80 B × 267 HE)



Figure 5



Figure 6

Figure 5. Radiograph on 3.4.1963. Slight callus formation is seen on the lateral side of the proximal part of the left femur and an extensive infiltration of the soft parts. No fracture visible.

Figure 6. Radiograph on 14.5.1963 shows abundant callus formation in the proximal part of the left femur.

a result of the earlier hyperplastic callus formation. Radiographic examination of the right femur on Dec. 2, 1966 (Figure 8) showed slight callus formation but no fracture. The patient was discharged for Christmas and readmitted one month later. He had had fever for two weeks. The right femur was now very swollen, red and inflamed, the clinical picture being similar to that of the left thigh 3½ years previously (Figure 7).

Radiogram of the right thigh on Jan. 16, 1967 (Figure 9) showed massive callus formation. Radiogram of the left femur (Figure 10) revealed extensive calcification in the proximal part as a result of the process in 1963. The bone formation overbridges the hip joint. Sedimentation rate 47. Hb 8.3 g. Erythrocytes [illegible]. Alkaline phosphatase 13.2 Bodansky units. [illegible]. Radiotherapy was commenced and the general condition improved. Regression of the tumour cannot so far be observed but the pain has been considerably alleviated.



F gure ı Appearance of the patient in January 1967 when a callus tumour developed in the right thigh which was swollen hot and tender



F gur 8 Ra li g aph on 9 1 1966 sh ws callus formation on the medial s de of the distal pa t f the right femur No fra ture visible

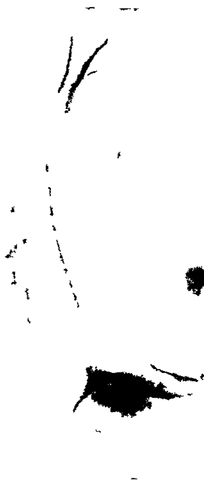


Figure 9



Figure 10

Figure 9 Radiograph on 16 1 1967 There is massive callus formation around the right femur X ray treatment was instituted

Figure 10 Radiograph on 16 1 1967 of the left femur shows an extensive callus formation as a result of the process in 1963 The bony formation overbridges the hip joint

COMMENTS

The patient's skeleton showed clear signs of osteogenesis imperfecta Before the age of eight he had had at least seven fractures in the lower extremities and also fractures of ribs When the patient was eight years old continuous treatment with anabolic hormone with intervals of two weeks was instituted During a subsequent follow up period of four years the patient had not had additional demonstrable fractures but there had been three episodes with formation of hyperplastic callus without fracture

In connexion with a release operation for flexion contracture of the hips there was a long period of fever which was interpreted as a streptococcal infection After this period the radiogram showed considerable persistent callus formation in the region of the left hip joint To what extent the operative trauma contributed to this callus formation cannot be decided

Nine months later there was marked swelling of the left thigh Fever increased sedimentation rate and anaemia were present Since both clinically and radiologically the process strongly resembled sarcoma biopsy was carried out Histological examination revealed undifferentiated chondroid (*Baker*) tissue the diagnosis of the pathologist being chondro myxo fibroma Biopsy was repeated one month later when histological examination revealed callus tissue The patient was given radiological treatment 2300 r after which there was evident regression of the process A thickening of the proximal part of the left femur persisted however after the inflammatory symptoms had ceased No fracture was observed

A similar process occurred in the right femur 3½ years later There was no fracture but massive callus formation took place simulating sarcoma clinically and radiologically Radiological treatment was instituted with evident amelioration of the patient s pain

This case resembles those described by *Strach* and *Koskinen* and two of *Fairbank* and *Baker*'s cases Since the disease is extremely rare it is natural that the clinician primarily suspects sarcoma In the beginning of the process in particular the histological picture is one of unorganized chondroid tissue which may mislead even the pathologist The most peripheral part of the process from which the sample is as a rule taken shows undifferentiated tissue while the central part shows callus tissue This has been demonstrated in *Baker* s and *Strach* s cases among others

As in *Strach* s case radiological treatment had an evident effect *Strach* points out that treatment must be instituted at an early stage when the process is progressing When more differentiated callus tissue is present the effect of radiological treatment is probably insignificant

There were severe inflammatory symptoms in the present case as also in the cases reported in the literature The calcium and phosphorus values were normal the alkaline phosphatases rising during the initial stage of the process

In one of *Brailsford* s cases sarcoma developed in a patient who

had previously had hyperplastic callus formation. Sarcoma in osteogenesis imperfecta has been reported by *Jewell & Lofstrom* and by *Werner*, among others.

In osteogenesis imperfecta there is normal chondroblast activity while the osteoblast activity is reduced (*McKusick* and others). In the present stage it is not possible to state what metabolic activity of the osteoblasts is injured (*Caniggia et al.*). Employing a tetracycline technique *Ramser & Frost* demonstrated faulty periosteal ossification in osteogenesis imperfecta in an adult woman. After fractures, however, the osseous tissue responds with good callus formation and pseudarthroses are rare. According to *McKusick*, *Follis*, and others osteogenesis imperfecta is a heritable disorder of the connective tissue which manifests itself in various ways. *McKusick* points out that a tendency to hypertrophic scars, as reported by *Scott & Stiris* in osteogenesis imperfecta, can be compared with the manner in which osseous tissue reacts with hyperplastic callus in certain cases. *Johansson* and *Sundberg* described severe calcification of the vessels of the extremities in osteogenesis imperfecta in the newborn.

On the basis of investigations with microradiography, polarized light microscopy and X-ray diffraction *Engfeldt et al.* point out that the immature fibrillary bone normally seen in foetus and newborn infant resembles in several ways the tissue found in osteogenesis imperfecta. Normally the primary bone is replaced by secondary bone after birth but in osteogenesis imperfecta this secundary bone is not found. It is also a well known fact that fractures in the newborn heal with extensive callus formation, partly perhaps because of faulty immobilization.

Without greater knowledge of the factors which control osteoblast activity, the delayed bone formation in osteogenesis imperfecta cannot be explained, nor why there is hyperplastic callus formation in certain cases.

SUMMARY

A case of osteogenesis imperfecta in an 8-year old boy is described, in which hyperplastic callus formation simulating osteogenic sarcoma developed in the left femur without fracture. The inflammatory signs were striking, with prolonged fever, elevated sedimentation rate and anaemia. The alkaline phosphatases were increased. After X-ray treatment there was evident regression. A similar process developed in the right femur 3½ years later, also without signs of fracture. The

pathology of the condition is briefly discussed The importance of recognising the true nature of the disease is stressed

RESUME

Un cas d osteogenese imparfaite chez un garçon age de 8 ans est decrit Il y avait dans ce cas une formation hyperplastique d un cal simulant un sarcome osteogenique qui s etait developpe dans le femur gauche sans fracture Les signes d inflammation etaient nets avec etat fievreux prolonge elevation du taux de la sedimentation et anemie Les phosphatases alcalines avaient augmente Apres un traitement aux rayons X on constata une regression marquee Un processus similaire s est developpe dans le femur droit trois ans et demi plus tard aussi sans signe de fracture Il est discute brievement de la pathologie de cet etat L importance qu il y a a reconnaitre la vraie nature de la maladie est soulignee

ZUSAMMENFASSUNG

In dem linken Femur eines 8 Jahre alten Junges der von Osteogenesis imperfecta leidete entwickelte sich eine sarkomahnliche hyperplastische Callusbildung ohne Fraktur Die inflammatorischen Symptome waren ausgepragt Der Patient hatte prolongierter Fieber gesteigerte Senkungsreaktion und Anemie Die alkalischen Phosphatase waren gesteigert Wahrend Rontgenbehandlung trat eine deutliche Regression ein Ein ahnlicher Prozess entwickelte sich 3½ Jahren spater in dem rechten Femur auch ohne Fraktur Die Pathologie des Zustandes wurde kurz beschrieben Die Verfassern pointieren die Wichtigkeit des Feststellens der richtigen Artdiagnose des Zustandes

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CORRECTION OF CONGENITAL SCOLIOSIS BY EXCISION OF ONE HALF OF A CLEFT VERTEBRA

Report of a Case

By

A LANGENSKIOLD

Received 26 i 67

Formerly it was a wide spread belief that congenital scoliosis does not become worse with growth However in recent years the great variations in prognosis in this group of scolioses has been emphasized by several authors (*Blount De N Hough Roaf Voe* and others)

The literature dealing with the possibilities of correction of congenital scoliosis by excision of hemivertebrae is scanty (*Compere von Lackum & De F Smith*) In 1951 *Wiles* on the basis of experience from two of his own cases warned against attempts at the resection of dorsal vertebrae in congenital scoliosis *Mantle* (1959) stressed that the presence of spina bifida in congenital scoliosis is a sign of poor prognosis Recently (1965) *Hodgson* reported examples of successful correction of fixed spinal curves by surgery

The individual variations in the pathological anatomy in cases of multiple congenital anomalies of the spine are very great As a consequence of this fact every progressing scoliotic curve in this group of cases presents an individual therapeutic problem Unpredictable growth factors may be brought into play by surgical intervention in the growing spine which was stressed by *Wiles* Therefore indications for operation must be considered with continence

CASE REPORT

M J a girl born April 29 1949 At birth it was noticed that the left lower extremity was weaker than the right The child was admitted to the Orthopaedic Hospital of the Invalid Foundation for the first time on July 19 1950 The left



Figure 1



F gure 2 Age ten y ars Marked lumba scoliosis Severe deviation of the trunk Rad ograph taken in a r cumbent position

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F gure 1 Ra l graph of the spine of a girl ag d one year and two months Multiple n malies of the lumbar spine The fourth lumbar vertebra is a cleft vertebra Sl ght scoli sis The other F gures in this article are pictures taken of th same pati nt



Figure 3



Figure 4 Tuo antero p sterior tomographs of the lumbar spine The distance between the planes was one cent meter

f t wa in a c lcaneo valgus position and the left lower limb was one centimeter horter than the right The fo t deformity was treated conservati ely The hips w re radi gr phically n m l There was a sl ght scolios of the lumbar spine wl ich h w l multiple an malie (Figure 1)

In 19 9 th c li is wa f und to l e rapidl progressing (Figure ?) In January 1960 at the age of ten year and n ne months the patient started to wea a Mil wa k e l rac There w s ever sc li sis and dev ati of the trunk (Figure 3) T m gr ph f the lumbar pine in two planes showed the anatomical deta ls f the f urth lumb a cleft vert bra (butterfly vertebra) The right part of it wa mu h greater than the left (Figure 4) Systematic muscle testing sh wed l r ll weakne of all mu cl of the left lower limb and around the left l ip Th l ft hip was ul luxated

On tl basi of th X ray f nding it was deci led to excise the right part of the l ft f urth vertebr On M rch 3 1960 the auth r excised the right part of the t t f th vertebra b a r ght lumbar mu cle pl tting incision The nucleus pulp s n l the artil ge ti sue s tuated between the two parts f the cleft verte

F gure 3 Ag ten years an l s en months The lumbar curve and the deviation of th trunk have progress d Ra liograph taken in a standing pos tion



Figure 3

bral body were also removed. The anterior surface of the spinal dura was exposed over a distance of two centimeters.

On April 20, 1960 the right part of the lamina of the fourth lumbar vertebra, the right lower articular process of the third vertebra and the right upper articular process of the fifth vertebra were removed by a posterior incision.

A week after the second operation muscle testing showed no change in the muscle power of the left lower extremity compared to the condition prior to the operations. Three weeks after the hemilaminectomy the patient was allowed out of bed in her Milwaukee brace.

Figure 5 shows a radiograph of the spine five months after the operations on the cleft vertebra. Figure 6 gives an idea of the degree of correction obtained by the operations.

For the congenital palsy and for the shortening of the left lower limb an extra-articular arthrodesis of the left subtalar joint, a Phemister epiphyseodesis of the right tibia and fibula and a Schanz osteotomy of the left hip were carried out at later stages.

Figure 8 shows the spine of the patient after the period of growth.

DISCUSSION

The main factor which was considered to justify an attempt to correct the scoliosis in this case by excision of a part of a cleft vertebra was the severe deviation of the trunk. Keeping the patient lying on the side opposite to the operation after the procedures and the use of a Milwaukee brace resulted in a correction of 25–30 degrees which was enough to bring the spine into balance (Figure 7). Today we might prefer in a similar situation to ensure this result by interbody fusion as suggested by *Hodgson*.

In this case, as in subsequently treated cases of congenital scoliosis, tomography of the anomalous part of the spine in two planes made an exact mapping of the details of the anomalies of the vertebrae possible. This is of decisive importance in the planning of the operations in these very varying conditions.

SUMMARY

In a girl with multiple anomalies of the lumbar spine, asymmetrical growth of the cleft fourth lumbar vertebra caused progressing scoliosis with severe deviation of the trunk (Figure 3). Excision of one part

---

Figure 5. Marked reduction of the lumbar curve after removal of the right half of the cleft L IV vertebra.



Figure 5



Figure 8 Radiograph of the spine taken in a standing position six and a half years after operations on the cleft vertebra



Figure 6 A Contour drawing of the lumbar spine as seen in Figure 3
B Contour drawing of the lumbar spine as seen in Figure 5

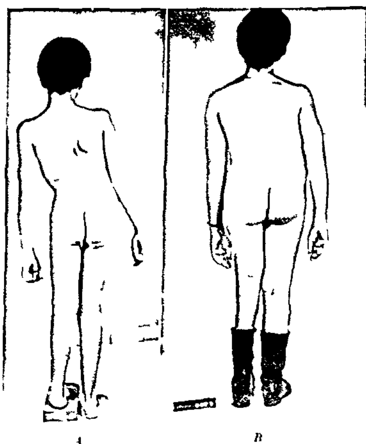


Figure 7 A Photograph of the patient before the operations on the cleft vertebra
B Photograph taken six and a half years after operation

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From the Orthopaedic Hospital of the Invalid Foundation Helsinki Finland
(Head A Langenskiold MD)

CHRONIC NON SPECIFIC TENOSYNOVITIS OF THE TIBIALIS POSTERIOR TENDON

By

A LANGENSKIOLD

Received 27 II 67

In 1954 the author was consulted by a woman who had tenderness and swelling in the region of the tendon sheath of the posterior tibial tendon Textbooks gave no support for a preoperative diagnosis and possible alternatives seemed to be tenosynovitis tumor or ganglion Operative exploration with discission of the tendon sheath and the microscopic finding revealed chronic non specific tenosynovitis with effusion The operation led to rapid permanent healing When the next case was encountered eight years later the condition was so similar that there did not seem to be much doubt about the diagnosis Since then four additional cases of this condition have been seen

Chronic non specific tenosynovitis with effusion of the posterior tibial tendon seems to be a rare condition Since inefficient conservative treatment without a diagnosis seems to be common in these cases and since a complete cure can be expected from operative treatment a report of the six cases seen by the author has been considered justified

In 1950 *Lapidus & Seidenstein* reported two cases of tenosynovitis of the posterior tibial tendon treated in the Hospital for Joint Diseases in New York They wrote Non specific chronic tenosynovitis must be considered a rarity particularly at the ankle A thorough search of the literature disclosed only one case somewhat similar to the authors Cases 2 and 3 that reported by *Kulowski* in which the posterior tibial tendon sheath was affected In both cases reported by *Lapidus & Seidenstein* incision and excision of the tendon sheath in one case total excision and in the other partial cured the condition

In 1955 A W *Fowler* reported seven cases treated by operation The following quotation from his brief report is given "The condition was

of the cleft vertebra gave a correction of 25–30 degrees which was enough to bring the spine into balance (Figures 7 and 8)

RESUME

Chez une fille ayant des anomalies multiples de la colonne lombaire une croissance assymetrique de la quatrieme vertebre lombaire fourchee causait une scoliose progressive avec grave déviation du tronc (Figure 3) L'excision d une partie de la vertebre donna une correction de 25–30 degres ce qui suffit pour remettre la colonne vertebrale en equilibre (Figure 7 et 8)

ZUSAMMENFASSUNG

Bei einem Madchen mit multiplen Anomalien der Lendenwirbelsaule verursachte asymmetrisches Wachstum einer Schmetterlingwirbel eine progressive Scoliose mit schwerer Dekompensation (Figure 3) Die Excision der einen Halfte der Schmetterlingswirbel gab eine Korrektion von 25 –30 die genug war um eine Kompensation wiederherzustellen (Figures 7 und 8)

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Operative findings	Microscopical finding	Result of operation	Follow up time	Condition at last follow up examination
hickening of the tendon heath covered by red anulations Yellow uid in tendon sheath	Non specific synovitis	Free of pain and tenderness two months after op	5½ years	No symptoms
hickening of the tendon edema and adhesions f tendon Usuration in ie tibial aspect of the nd on sheath	–	Free of pain and tenderness a few months after op	3 years	Free of pain Persisting valgus of the foot
artial rupture of the end n Reddish brown anulations and viscid luid in the tendon heath Thickening of nd n sheath	Chronic non specific synovitis	Slight tenderness five months after op Patient satis fied with result of treatment	1 year and 9 months	Free of pain Some thickening in the region of the scar
edema outside the end n heath Reddish ranulations and clear luid in the tendon heath which had hi kened	Chronic non specific syno itis	Free of pain and tenderness a few months after op	1 year and 8 months	Free of pain Some thickening in the region of the scar
e ldish g anul ti n n the t n l n an l in its heath Clea yellow luid in the heath	Chronic teno synovitis	Free of pain one month after op	Two months	–
e ldish g anul ti ns le yello flui l in the h t thi k ning f t nd n	Chronic t no novitis	Free of pain six weeks after op	1 years	Free of pa n

literature by the present author In 1956 *Hauser* reported good results of treatment of tenosynovitis at the ankle by Hydrocortone injections His series included only one case of tenosynovitis with effusion of the tibialis posterior tendon In this case the condition was relieved after operation

In 1963 *Williams* reported fifty two cases of chronic non specific

Tab

Case No	Age when first seen (years)	Duration of symptoms before diagnosis	History	Sedimentation rate before operation
1	64	A few months	Local tenderness. Pain when walking	Record destroyed.
2	56	2 years	Chronic tenderness after acute stage. Progressing valgus of the foot	29 mm/1 hour
3	46	7 years	Chronic tenderness. Pain when walking	8 mm/1 hour
4	52	5 months	Accessory scaphoid excised from the same foot with good result six years earlier	12 mm/1 hour
5	59	6 months	Tonsillitis six months before swelling of ankle	29 mm/1 hour
6	60	8 months	Chronic tenderness after acute stage	34 mm/1 hour

seldom diagnosed early and it was often mistaken for osteoarthritis of the ankle and treated conservatively without relief. At operation the tendon sheath was found to be swollen and thickened and the tibialis posterior tendon was greatly enlarged. The inflamed synovium was excised with relief in all cases.

Three additional reports of this condition have been found in the

de resultat mais une incision sur la gaine du tendon et l enlevement du tissu granule a apporte un soulagement dans tous les cas

ZUSAMMENFASSUNG

Sechs Falle von chronischer unspezifischer Tenosynovitis der Sehne des Musculus tibialis posterior werden beschrieben Konservative Behandlung hatte versagt aber Incision der Sehnenscheide und Entfernung von Granulationsgewebe wurde in allen Fallen von Heilung gefolgt

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Il user E D W (19 6) Nonspecific Tenosynovitis with Effusion at the Ankle *I stgrad Med* ?0 365

Lapidus P W & Seidenstein H (1950) Chronic Non specific Tenosynovitis with Effusion about the Ankle *J B ne Jt Surg* 32 A 175

Williams R. (1963) Chronic Nonspecific Tendovaginitis of Tibialis Posterior *J Bone Jt Surg* 45 B 54?

tendovaginitis of tibialis posterior. In twelve of these cases division of the tendon sheath was performed with complete relief in eleven. In 1965 *Cozen* reported five cases in one of which operation was carried out.

CASE REPORTS

The reports of the six cases seen by the present author are summarized in Table 1. All the patients were females aged between forty six and sixty four years. They had all been working in occupations in which standing for long periods is required. Otherwise no common factor of possible etiological significance could be pointed out. In two cases the symptoms had been present for years resisting conservative treatment before operation gave relief.

The local signs were very typical as swelling and tenderness was strictly located to the area of the posterior tibial tendon sheath. At systematic palpation there could be no doubt about which organ was tender.

All affected feet showed a marked valgus tendency. This had appeared and progressed markedly after the pain occurred. This progressing valgus tendency has been interpreted by the present author as a sign of reflectory weakness of the tibialis posterior muscle. *Cozen* interpreted the tenosynovitis as an irritation secondary to valgus strain. Possibly both factors contribute to the clinical picture.

At the operation oedema, viscid fluid and reddish granulomatous tissue in the tendon sheath was a regular finding. At all the operations the tendon sheath was incised along its whole length and was not sutured when the wound was closed. Radical excision of the whole tendon sheath was not carried out in any of the cases but reddish granulations were curetted from the sheath and from the tendon itself. Adhesions between the tendon and its sheath were excised and in most cases a part of the tendon sheath was removed.

After the operations oedema around the scar mostly persisted for several weeks. When the sutures were removed walking was already less painful than before operation and after a couple of months the tenderness of the scar had subsided. Some thickening of the region of the tendon sheath regularly persisted but was not disturbing. A foot support was prescribed to all patients in order to promote the return of power of the tibialis posterior muscle.

SUMMARY

Six cases of chronic non specific tenosynovitis of the tibialis posterior tendon are reported. Conservative treatment had failed but incision of the tendon sheath and removal of granulation tissue gave relief in all cases.

RÉSUMÉ

Six cas de ténosynovite chronique non spécifique du tendon tibial postérieur sont rapportés. Un traitement conservateur n'a pas donné

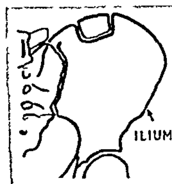


Figure 1



Figure 2

Figure 1 Schematic drawing of the area from which the bilaminar iliac bone graft is taken

F gure Schematic drawing of the bilaminar graft from the ends of which the spongy bone and the middle part of the cortex of the crest have been removed





F gu 3 Schem t c draw ng of the manner in whi h th ma si e bone graft is welg d n the sp n us proc ss s Chips of liac bon are implanted betwe n the lam na on b th si l s of the ma sive g aft

Acta orthop Scandinav *38* 306–312 1967

From the Orthopaedic Hospital of the Invalid Foundation Helsinki Finland
(Head Professor A Langenskiold M D)

SPINAL FUSION BY FIXATION WITH A BILAMINAR ILIAC BONE GRAFT WEDGED ON THE SPINOUS PROCESSES IN THE SAGITTAL PLANE

By

A LANGENSKIOLD

Received 26 1 67

In September 1960 *Besa* described a new method for spinal fusion Without knowledge of *Besa* s work the present author used the same method for the first time in May 1959 The impulse to develop the operation was given by the desire to get patients out of bed early after operative fusion of two lumbar vertebrae without endangering the result Since the first operation the author has used the method in twenty one cases During the same period about two hundred patients were operated on for a protruded intervertebral disc by the author This means that the indications for the method in question have been considered limited

OPERATIVE TECHNIQUE

Before the transplant is taken from the ilium the spinous processes and the laminae of the vertebrae which are to be fused are exposed If exposure of nerve roots and intervertebral discs is indicated in the particular case this is done before the processes and laminae are prepared for application of the transplants The cortex is partly removed from the spinous processes and from the posterior aspects of the laminae All soft tissues are removed from the space between the two spinous processes

From the middle part of the iliac crest a piece of bone comprising about four centimeters of the entire thickness of the crest is taken with a chisel A suitable size of the iliac graft is usually 4 × 3 centimeters (Figure 1) From both ends of the bilaminar graft the spongy

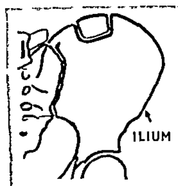


Figure 1

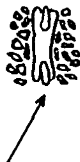


Figure 2

Figure 1 Schematic drawing of the area from which the bilaminar iliac bone graft is taken

Figure 2 Schematic drawing of the bilaminar graft from the ends of which the spongy bone and the middle part of the cortex of the crest have been removed





SPINOUS PROCESS

Figure 3 Schematic drawing of the manner in which the massive bone graft is wedged on the spinous processes Chips of iliac bone are implanted between the laminae on both sides of the massive graft

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Figure 4 B

exposed on one side chips are implanted only on the contralateral side In the presacral interspace the method can be used only when the sacral crest is well developed The muscles covering the defect in the iliac crest should be sutured with non adsorbable material to prevent formation of hernia (cf *Bosworth* 1955)

MATERIAL

In nine c e fusi n of two lumb ar vertebrae was perfo med when operating for the r m al of recurrent disc pr trusion (Figure 4) In f u cases pondylodesis wa arried ut f r chr nic backache f m severe degenerati n f one single lumbar l In three a of sciatica the igns of degeneration of the disc was considered t ive t in l cate s mpl emoval f the protru led mas an l fusi n was per f med at the sam operati n (Figure 5) In f ur cases the operation was carried ut f r h nic ba ka he with l calize l tenderness in one interspace but without ntgen l g cal ign of se ere legeneration of the di c In one case the indi c ti n l eration was re idual equels of tubercul sis in t o vertebrae

The l lest patient in the series was fifty five ears old A girl aged eighteen with heal d tubercul s of the vertebrae L III L IV was the only patient under tw nty ears In ele n patient the operation was carried out in the interspace L IV L V in eight l etwe n L V and the acrum an l in one between L III and L IV



Figure 4 A

Figure 4. Antero-posterior and side view radiographs of the same lumbar spine in which fusion of the interspace L IV–L V had been performed in connection with the third operation for protrusion of the same disc. The radiographs were taken one week after the operation. One year later the patient was free of pain and the mobility of the spine was good. No mobility of the fused area in radiographs taken in extreme flexion and hyperextension.

bone between the laminae and the middle part of the cortex of the crest are removed. The graft is then H-shaped when seen from the side of the crest (Figure 2). The space between the two spinous processes is widened by suitable positioning of the operating table before the graft is hammered in place with a bolt. The graft is wedged on the spinous processes in question so that the laminae of the graft cover the lateral surfaces of the processes (Figure 3).

The spondylodesis is completed by implantation of bone chips from the ilium lateral to the massive graft (Figure 3). If the dura has been



Figure 4 B

exposed on one side chips are implanted only on the contralateral side In the presacral interspace the method can be used only when the sacral crest is well developed The muscles covering the defect in the iliac crest should be sutured with non adsorbable material to prevent formation of hernia (cf *Bosworth* 19..)

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Figure 5. Antero-posterior radiograph of a spine in which fusion of the fifth lumbar vertebra to the sacrum had been carried out. The radiograph was taken five days after the operation. Six months later the patient was free of pain and the mobility of the spine was good. Radiographs in bent position indicated solid fusion.

One patient was operated on twice, first in the interspace L IV–L V and later in the presacral interspace.

Ten patients were out of bed on the first or second day after the operation, *six on the third to sixth day and four on the twelfth to sixteenth day. After* healing of the wound the patients were allowed to live a normal life but were recommended to avoid work in a bent position and avoid sudden bending of the spine. Systematic exercise of extension and flexion of the back was started four months after the operation. At the same time fusion was tested in twenty patients by taking side view radiographs in extreme hyperextension and extreme flexion of the back.

In eighteen cases side view bending radiographs showed no mobility in the fused interspace. In two cases the presence of a pseudarthrosis could be proved. *In both* these cases it had been necessary to remove the articular processes on one side in the interspace L IV–L V. Three patients had persistent backache in spite of radio*graphy suggesting* fusion. In these cases there were strong reasons to suspect a psychogenic basis for the complaints. In sixteen cases good mobility *of the spine*

was proved at examination six months after operation and thirteen patients could be followed up for more than one year

DISCUSSION

In 1948 *Cleveland Bosworth & Thompson* pointed out that One should avoid covering any greater number of spinal intervals than are absolutely essential in performing a fusion at the lumbosacral juncture but the fusion should always extend to and include the sacrum (p 311) This principle partly explains why the present author has used the method described in only twenty one cases in eight years However there are cases in which recurrent disc protrusion in the L IV–L V interspace makes fusion of the vertebrae highly desirable and the L V–S disc shows only slight or no signs of degeneration To carry out a fusion of two interspaces in these cases would mean protracted recumbency because the author has not been convinced that immobilisation for several weeks can be avoided after fusion of two interspaces in the lumbar spine without endangering the result of the operation

If our patients can be allowed to be out of bed a few days after operative fusion of the vertebrae L IV–V without too great a risk of pseudarthrosis there are reasons for carrying out such a fusion more often than we have been inclined to do The disadvantage of prolonged recumbency after orthopaedic operations in adult patients is today well recognized The experience gained with the method described seems to indicate that it makes it possible to avoid a long period of recumbency after fusion of one single interspace in the lumbar spine

The indications for spinal fusion in this series correspond to those defined by *Howorth* in 1961

SUMMARY

In 1960 *Besa* described a new method of spinal fusion by fixation with a bilaminar H shaped iliac bone graft wedged on the spinous processes in the sagittal plane Without knowledge of *Besa*'s work the present author used the same method for fusion of one single lumbar interspace in May 1959 The operation has been carried out by the author in twenty one selected cases It seems to allow early mobilisation of the patient without too great a risk of pseudarthrosis and it is recommended when fusion of one lumbar interspace is indicated For fusion of the fifth lumbar vertebra to the sacrum the method can be used only if the sacral crest is well developed

RÉSUMÉ

En 1960 *Besa* a décrit une nouvelle méthode de fusion vertébrale par fixation au moyen d'une greffe osseuse iliaque bilamminaire en forme de H enfoncée au milieu des processus vertébrales en le plan sagittal. Sans avoir eu connaissance de l'ouvrage de *Besa*, le présent auteur a eu recours à la même méthode en mai 1959 pour établir la fusion entre deux vertèbres lombaires lorsqu'il s'agissait d'un *seul espace intervertébral*. L'opération a été pratiquée ensuite par l'auteur dans vingt et un cas sélectionnés. Elle semble permettre la mobilisation rapide du malade sans grand danger de pseudarthrose et elle est recommandée lorsqu'il d'un seul espace intervertébral lombaire. Pour la fusion de la 5ème vertèbre lombaire au sacrum, la méthode ne peut être utilisée que si la crête sacrée est bien développée.

ZUSAMMENFASSUNG

Im Jahre 1960 hat *Besa* eine neue Methode beschrieben, mit der eine Spondylodese mit einem H-förmigen Transplantat vom Ilium, das die beiden Knochenplatten des Darmbeins umfasst und in der Sagittalebene auf die Dornvortsätze der Wirbeln festgekeilt wird.

Ohne Vorwissen von der Arbeit von *Besa* hat der Verfasser diese Methode für die Spondylodese von zwei Lendenwirbeln seit Mai 1959 angewandt. Die Operation ist vom Verfasser in einundzwanzig ausgewählten Fällen angewandt worden. Die Methode scheint eine frühe Mobilisation der Patienten zu erlauben ohne ein zu grosses Risiko für Pseudarthrosenbildung. Sie wird rekommendiert, wenn eine Spondylodese von zwei Lendenwirbeln indiziert ist.

Für eine Spondylodese zwischen der fünften Lendenwirbel und dem Kreuzbein kann die Methode benutzt werden nur wenn die Crista Sacri gut entwickelt ist.

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From the Orthopaedic Hospital of the In alid Foundation Helsinki Finland
(Head Professor A Langenskiold M D)

VARUS AND VALGUS DEFORMITY OF THE ELBOW FOLLOWING SUPRACONDYLAR FRACTURE OF THE HUMERUS

By

A LANGENSKIOLD & R KIVILAAKSO

Received 20 ii 67

Supracondylar fracture of the humerus is a common injury in children and in Scandinavian medical literature much attention has been paid to it (*Avellan* 1933 *Sandegard* 1943 *Holmberg* 1945) However little has been written about the treatment of the unsightly deformities of the elbow which sometimes follow this type of fracture The functional end result is uniformly adequate with practically all methods of treat ment of the supracondylar fractures of the humerus but the incidence of carrying angle change is unnecessarily high (*Smith* 1960)

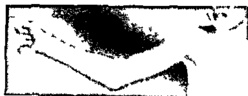
The most common deformity following supracondylar fracture is cubitus varus the incidence of which according to the literature varies between 9 and 57 per cent (*Hoyer* 1952) Cubitus valgus is less common but more harmful because it carries the risk of progressive palsy of the ulnar nerve (*Gay* and *Love* 1947)

MATERIAL

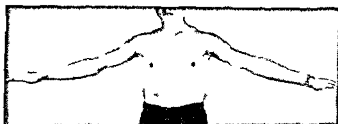
Between 19 8 nd 1966 fou teen patients were treated in the Orthopaed c Hospital f the Invali l F undat n f r deformity including a change of the carrying angle f th elb w after u pracondylar fractu e of the humerus Seven of the patients were b s an l s ven were g rls They h d all been prim rily treated elsewhere fr the f acture and c me to the hospital f r correcti n of the established deformity

Hist ry The age of the patients at the time of fractu e varied between two n l eight years In one ca e the c use of the fracture was a bicycle accident in the oth ca s it wa a fall from a height of from a half to two meters

One patient ha l been primaril treated by open reduction and six had been conservatively treated in h spital Four ch ldren had been treated in plaster as out patients one b y a bone setter and two had had no primary treatment at all



A



B

Figure 1. A. Photograph of a boy aged ten years. A supracondylar fracture had been treated nine years previously by open reduction. Valgus 35 degrees and 40 degrees limitation of extension.
B. The same boy five years after operative correction of deformity. Normal valgus, 20 degrees limitation of extension.

The time which had elapsed between the injury and admission to the hospital for correction of deformity varied from two months to fifteen years. According to the parents, the deformities had mostly been apparent when the mobility of the elbow returned after immobilisation. In no case had gradual progression or gradual correction by growth been observed with certainty.

Condition before correction. The age of the patients on admission to the hospital varied between four and a half and eighteen years. Cubitus valgus (Figure 1) was present in three cases and varied between twenty five and thirty-five degrees. All these patients had a limitation of extension of twenty to fifty degrees, the rotation movements being slightly impaired. One patient, who had a valgus deformity of twenty five degrees, had a palsy of the ulnar nerve. This began to appear five years after the injury and had gradually progressed for four years. In all three cases, the valgus deformity was somewhat impairing the function of the limb.

Cubitus varus (Figure 2) was seen in eleven patients, with a deformity of twenty five to forty degrees. Almost all patients had some limitation of extension and flexion of the elbow and some of them had slight limitation of rotation. Neither the patients nor their parents complained about impaired function of the limb but it was the unsightliness of the deformity that caused the desire for its correction.

Operation. In cubitus varus the distal end of the humerus is exposed subperiosteally through a lateral incision. Proximal to the joint, a wedge shaped piece of bone is removed (see Figure 3 A). The angle of the wedge should correspond to the degree of correction from varus deformity aimed at to a normal position of slight



A



B

Figure 2 A Photograph of a girl aged four and a half years Supracondylar fracture of the humerus treated two years previously in plaster Varus deformity 30 degrees

B The same girl five years later Corrected to normal position after two operations

valgus The cut surfaces of the bone are approximated and a possible deformity of rotation is corrected by rotating the distal fragment outwards The fixation of the fragments can be suitably achieved by a metal plate which is bent to correspond to the shape of the surface of the bone and fixed by short screws perforating the lateral cortex only (Figure 3)

The fossa olecrani and the fossa coronoidea should not be penetrated by the screws and penetration of the epiphyseal cartilage should be avoided in growing individuals A plaster cast reaching from the fingers to the axilla is applied

In cubitus valgus the operation is correspondingly carried out from the medial side and when necessary the ulnar nerve is transposed to the anterior aspect of the elbow

RESULTS

In the cases of cubitus valgus a normal position was achieved without reoperation (Figure 4) In the patient with the ulnar palsy the nerve was transposed anteriorly After a year the palsy had disappeared and the function of the hand was normal

In two cases of cubitus varus a reosteotomy had to be carried out

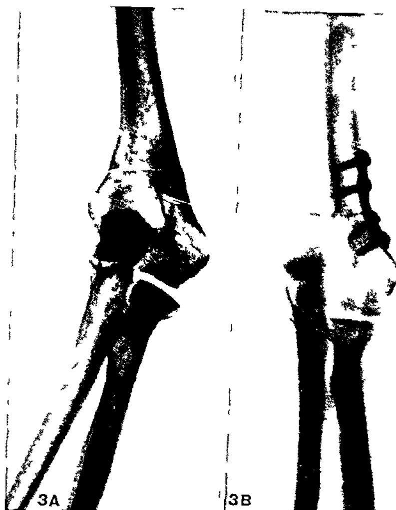


Figure 3 A. Cubitus varus in a girl aged eighteen years. Supracondylar fracture at the age of three years.
B. The same elbow radiographed on the operating table immediately after correction of varus and rotation deformity and fixation by a bent metal plate.

because too much varus was left uncorrected at the first operation. In seven cases the final result of operation was a normal carrying angle, in two cases normal valgus was lacking (Figure 5) and in two cases there was slight varus. In both these the varus position was less than ten degrees and reoperation was not considered necessary.

After operative correction of the carrying angle the mobility of the elbow joint remained unchanged or increased. In no case was there decreased range of motion at follow-up examination, not even in the patients who underwent two operations.

In one case the follow-up time was six months, in two cases one

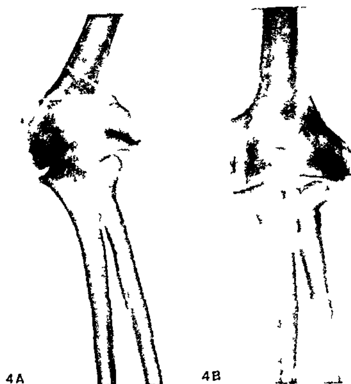


Figure 4 A Cubitus valgus in a boy aged fourteen years Valgus 30 degrees limitation of extension 35 degrees limitation of supination
B The same elbow three years after operative correction of deformity Normal valgus limitation of extension decreased to 90 degrees supination still limited

and a half years and in the other cases over two years The average follow up time was three and a half years

DISCUSSION

The pathogenesis of the change of the carrying angle of the elbow causing deformity after supracondylar fractures of the humerus has been the subject of discussion *Madsen* (1956) was of the opinion that the most common cause of cubitus varus is unreduced inward rotation of the distal fragment after fracture Growth disturbance is frequently blamed as a cause of change in the carrying angle *Brewster & Karp* (1940) examined eight cases of cubitus varus deformity and found that clinical measurements of the lengths of the outside of the arm exceeded those of the inside by one quarter of an inch in six cases They con

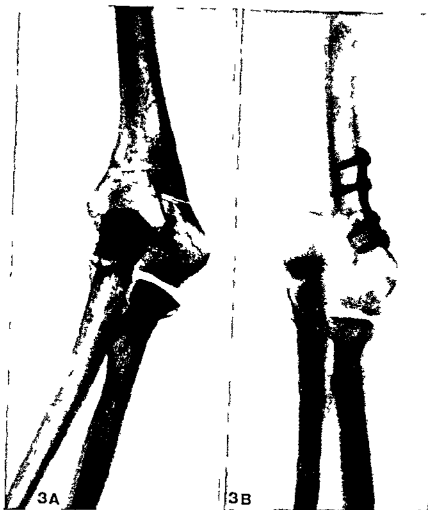


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For retaining the position of the fragments after osteotomy and correction their fixation is important Thus the operative methods formerly proposed (*King & Secor* 1951 *French* 1959) imply internal fixation *Watson Jones* (1955) did not use internal fixation but applied a plaster cast with the elbow in an extended position The method described by the present authors seems to ensure the position of the fragments in a plaster cast applied with the elbow flexed to a right angle Before the plaster cast is applied the degree of correction can be checked in full extension without the risk of changes in the position With the elbow joint in flexion the degree of correction is almost impossible to estimate When a varus deformity is corrected the normal valgus position of the elbow should be taken into account a fact often easily neglected

SUMMARY

In three cases of cubitus valgus and eleven cases of cubitus varus appearing after supracondylar fracture of the humerus the deformity was corrected by wedge resection of the bone and fixation of the fragments by a bent metal plate (Figure 3) In the cubitus valgus cases a normal position was achieved Seven of the cubitus varus cases were corrected to a normal degree of valgus in two cases the normal valgus position was lacking after operation and in two cases slight varus remained In all cases the mobility of the elbow was found to have remained unchanged or increased at follow up examination

RESUME

Dans trois cas de cubitus valgus et dans onze cas de cubitus varus qui se sont produits après fracture supracondylaire de l humerus la déformité corrigée par resection en coin de l os et fixation des fragments par une plaque métallique courbe (Figure 3) Dans les cas de cubitus valgus une position normale a été obtenue Sept cas de cubitus varus ont été corrigés à un degré normal valgus dans deux cas la position valgus n a toutefois pas été obtenue et dans deux cas un faible varus a subsisté Dans tous les cas la mobilité du coude a été trouvée inchangée ou accrue lors d un examen complémentaire

ZUSAMMENFASSUNG

In drei Fällen von Cubitus valgus und elf Fällen von Cubitus varus nach suprakondylärer Fraktur des Humerus wurde die Deformität

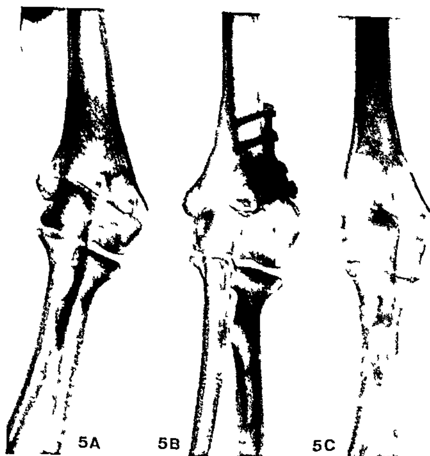


Figure 5 A Cubitus varus in a girl aged fifteen years Supracondylar fracture at the age of twelve years Varus 30 degrees limitation of flexion 20 degrees
B The same elbow one year after osteotomy and wedge resection No varus but normal valgus is lacking
C The same elbow four and a half years after correction Plate and screws removed

cluded that this had been caused by stimulation of the external epicondylar and capitellar epiphyses *Smith* (1960) did not consider growth disturbance the cause but thought that change in the carrying angle of the elbow after supracondylar fractures of the humerus is caused by medial or lateral angulation of the distal fragment

We did not see our patients when the deformity appeared because the primary treatment was given elsewhere However in none of these cases was there a definite history of gradual increase of deformity When correction was achieved gradual recurrence was not seen in any of the cases although the operation in ten of them was performed during the growth period Thus our observations do not speak in favour of the idea that these deformities are caused by growth disturbance

For retaining the position of the fragments after osteotomy and correction their fixation is important Thus the operative methods formerly proposed (*King & Secor* 1951 *French* 1959) imply internal fixation *Watson Jones* (1955) did not use internal fixation but applied a plaster cast with the elbow in an extended position The method described by the present authors seems to ensure the position of the fragments in a plaster cast applied with the elbow flexed to a right angle Before the plaster cast is applied the degree of correction can be checked in full extension without the risk of changes in the position With the elbow joint in flexion the degree of correction is almost impossible to estimate When a varus deformity is corrected the normal valgus position of the elbow should be taken into account a fact often easily neglected

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In drei Fällen von Cubitus valgus und elf Fällen von Cubitus varus nach suprakondylärer Fraktur des Humerus wurde die Deformität

durch Keilresektion und Fixation mit einer gebeugten Metallplatte korrigiert (Figure 3). In den Fällen von Cubitus valgus wurde eine normale Stellung erreicht. In sieben Fällen von Cubitus varus wurde eine normale Valgusstellung erlangt, in zwei Fällen fehlte die normale Valgusstellung und in zwei Fällen wurde die Varusstellung nicht ganz vollständig korrigiert. In allen Fällen war die Beweglichkeit des Ellenbogengelenks bei der Nachuntersuchung ebenso gut wie oder besser als vor der Operation.

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From the Clinic for Orthopaedics and Traumatology University of Helsinki
(Head Professor K E Kallio)

POSITIONING OF THE PULLEY MECHANISM WHEN RECONSTRUCTING DEEP FLEXOR TENDONS OF FINGERS

By

KAUKO A SOLONEN & PAUL HOYER

Received 3 iii 67

In reconstructive surgery of deep flexor tendons of the fingers it is of considerable importance to leave or to reconstruct pulleys to ensure the correct alignment and run of the tendons The literature seems to pay little attention to the question of what is the most favourable position for each pulley from the mechanical point of view

We have tried to determine these positions mathematically

We have assumed that

1 The force which the muscle exerts on the tendon is independent of the positions of the pulleys
2 There is no friction in the pulleys
3 The tendon is long enough to allow complete extension of the finger
4 The proximal pulley is always situated close to and on the proximal side of the metacarpo phalangeal joint
5 The two distal pulleys and the distal insertion of the tendon can be chosen at will

Our goal has been to find a construction which makes it possible for the finger to act like a normal finger *i e* to create a state where full range of movement is achieved with the smallest possible excursion of the muscle and where the moments or torques about the joints are neither too great nor too small

In the following we suppose that when a pulley is placed close to a joint it is flexible enough to turn in accordance with the joint and its direction bisects the angle of the joint

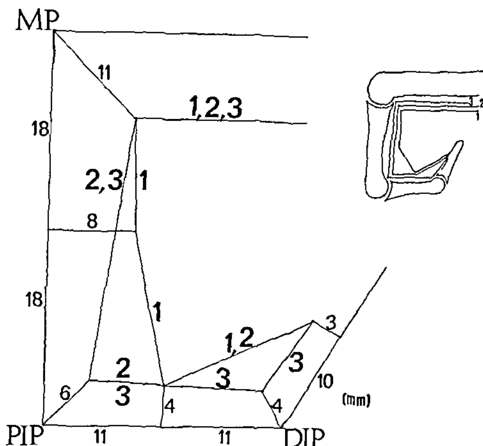


Figure 1. Three alternative pulley mechanisms

In order to obtain results that are easy to compare with each other we have considered three given arrangements (Figures 1.1, 1.2, 1.3). We have not attempted to arrive at general formulae for the moments and tendon excursion as functions of the angles but rather to calculate their values in the extension (0°) and flexion states (by maximal flexion we mean in these calculations 90°, except in the distal interphalangeal joint where 60° flexion is considered maximal). We are only discussing a typical finger and so we have used numerical values (Figure 2) throughout the calculations. We are only interested in comparing the different configurations, not in absolute values.

In calculations of the moment (M) of the tendon force (F) about a joint the moment is defined as the force times the perpendicular distance (d) of its line of action from the joint: $M = F \cdot d$. Because the tendon is in equilibrium the force (F) at any point (P) of the tendon is equal and opposite to the sum of all forces acting on the tendon at points distal to P. All we have to do, then, is to determine which pulley is closest to the joint on its distal side and take as the line of action the direction of the tendon on the proximal side of the pulley (Figure 3).

In the following we denote the moments of the flexor profundus force (F) about the metacarpo-phalangeal (MP), proximal interphalangeal (PIP) and distal interphalangeal (DIP) joints by M_{MP}, M_{PIP} and M_{DIP} respectively. By the excursion

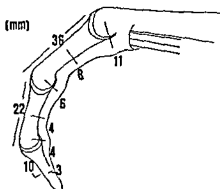


Figure 2 Measurements of bones of a normal finger

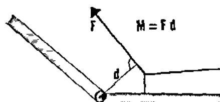


Figure 3 Calculation of the moment of the flexor tendon force about a joint

Δl we understand the difference in length in the extension and flexion states of the p rti n of the ten l n which lies in the finger (*i e* the excursion in the MP joint) All lengths are measured in millimetres The values have been found graphically

Alternative 1 (Figure 1 1)

The pulleys are placed in the middle of the proximal and middle phalanges

Results

	Extension	Flexion
M_{MP}	11 F	7 5 F
M_{PIP}	6 F	11.5 F
M_{DIP}	3 5 F	8 F
Δl		36.5 mm

Alternative 2 (Figure 1 2)

The proximal pulley is placed just at the PIP joint the distal one in the middle of the middle phalanx

Results

	Extension	Flexion
M_{MP}	11 F	8 8 F
M_{PIP}	6 F	4 3 F
M_{DIP}	3 5 F	8 F
Δl		30 mm

Alternative 3 (Figure 1 3)

Both pulleys are placed at the interphalangeal (IP) joints

Results

	Extension	Flexion
M_{MP}	11 F	8 8 F
M_{PIP}	6 F	4 3 F
M_{DIP}	3 F	3 5 F
Δl		28 mm

In the normal finger (Figure 4) the moments are remarkably constant for all angles

M_{MP}	11 F
M_{PIP}	6 F
M_{DIP}	4 F

For the flexion state the moments are likely to be slightly smaller. The excursion is somewhat smaller than in alternative 3

From the results above we may conclude that for all alternatives the moments in extension are approximately equal to those of the normal finger With flexion the moment about the MP joint decreases slightly more in alternative 1 than in 2 and 3 In the normal finger M_{MP} is greater than in any of the cases 1 2 3 but the difference is small The main difference between the three alternatives is that

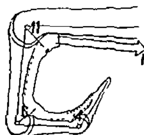


Figure 4 Deep flexor tendon of a normal finger

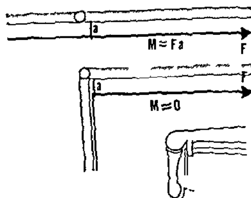


Figure 5 A rigid pulley close to a joint results in very small flexion moment

the moment tends to grow very big about a joint which is without a pulley Thus in alternative 1 for example M_{PIP} and M_{DIP} are twice as big as in the normal finger This situation may upset the equilibrium of the finger and prevent complete extension Particularly in alternative 1 the amplitude of excursion necessary for the complete range of movement of the finger is considerably greater than in the normal case Alternative 3 seems to be the one most nearly resembling the normal situation the excursion is shortest and there are no excessive moments The moments are in fact smaller than in normal which particularly in the PIP joint might cause some trouble with flexion

A distal shift of the insertion of the profundus tendon increases M_{DIP} and excursion in alternative 1 and 2 but has no noticeable effect in alternative 3 If we consider a case where the pulley remains orthogonal to the phalanx even during complete flexion (90) we find that at this angle the moment becomes vanishingly small (Figure 5) provided that the pulley is close enough to the joint Thus it seems to us that if the pulley is so strong that it withstands the torque which the tendon exerts on it it should be placed at some distance from the joint On working out the effect of this position of the pulleys we were somewhat surprised to find that from the mechanical point of view there is no difference between a construction in which the pulley lies some distance proximally of the joint and one in which it is situated equally far distally of the joint (assuming that the tendon is approximately parallel to the phalanx) (Figure 6) As is to be expected this construction is intermediate between alternatives 1 and 3 The moments can be made roughly equal to those of a normal finger

90° MAX 0°

$M = Fb$ $\Delta l = a+b$ | $M = F\sqrt{a^2+b^2}$ | $M = Fa$

$M = Fb$ $\Delta l = a+b$ | $M = F\sqrt{a^2+b^2}$ | $M = Fa$

$M = \frac{1}{\sqrt{2}}\ Fa \sim 0.7\ Fa$ $\Delta l = 1.4a$ | $M = Fa$

Figure 6 Moments and excursions when the pulley is situated distally proximally or just at a finger joint

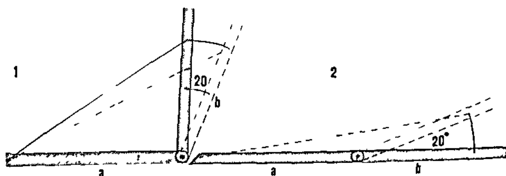


Figure 7 Demand for full flexion is uneconomical (cf text)

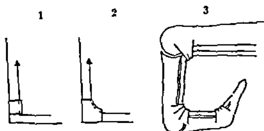


Figure 8 A broad pulley at the joint secures a good glide for the tendon

by placing each pulley at a distance of approximately 0 8 times the height of the pulley from the centre of the joint This gain in moment however has to be paid for by a corresponding demand for increase in the excursion of the tendon

It should be emphasized that it is very uneconomical with regard to the excursion to demand full flexion Let us consider the theoretical example of figure 7 If we want to bring the two rods the last 20 to full flexion (Figure 7 1) and the last 20 to full extension (Figure 7 2) respectively we shall find that the flexor excursion needed in Figure 7 1 $\Delta l_1 = 0\ 34\ \frac{ab}{\sqrt{a\ +b}}$ and that needed in Figure 7 2 $\Delta l = 0\ 06\ \frac{ab}{a+b}$ If $a = b$ this gives $\Delta l_1 = 8\ \ \Delta l$

When talking about the tendon excursions in the alternatives reviewed above however we must bear in mind that the excursion of the muscle is longer than we have calculated The reason is that we have omitted the excursion in the wrist The relative *differences in* excursion in the various alternatives are therefore not so great as they would seem to be from the above calculations

As regards the frictional effects in the pulleys we would point out that the pull of the tendon tends to turn the pulley in such a way as to make gliding as smooth as possible If the pulley withstands the torque however the tendon will turn sharply at one edge of the pulley (Figure 8 1) instead of turning equally at both edges This will increase the friction Physically the best arrangement seems to be one with broad pulleys at the joints (Figure 8 2) This will greatly reduce the sharp angles increase the moment and lessen the need for excursion Such an arrangement would result in action fairly similar to that of a healthy finger (Figure 8 3)

90° MAX 0°

$M = Fb$ $M = F\sqrt{a^2+b^2}$ $M = Fa$

$\Delta l = a+b$

$M = Fb$ $M = F\sqrt{a^2+b^2}$ $M \approx Fa$

$\Delta l = a+b$

$M = \frac{1}{\sqrt{2}} Fa \sim 0.7\, Fa$ $M = Fa$

$\Delta l = 1.4a$

Figure 6 Moments and excursions when the pulley is situated distally proximally or just at a finger joint

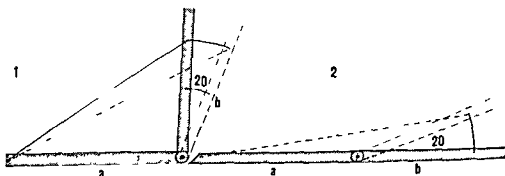


Figure 7 Demand for full flexion is uneconomical (cf text)

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From the Orthopaedic Hospital, Copenhagen, Hand Clinic. Head: K. Bang Rasmussen

EXPERIENCE OF FLATT FINGER JOINT PROSTHESES

By

L. ZACHARIAE

Received 14.XII.66

INTRODUCTION

Restoration of function in damaged finger joints has always been a challenge to surgeons and a problem which they are anxious to solve because finger joint function is of such great importance to the total function of the hand and thereby to the rehabilitation of hands damaged by trauma or by disease. Grafting of joint surfaces or whole joints has been reported in some cases with good results (*Graham* 1954).

Like alloplasty of the knee and hip joints, it has recently been attempted to insert endoprostheses into finger joints in traumatic cases (*Brannon* 1959) as well as in rheumatoid arthritis (*Flatt* 1961, 1963). It seems logical to try this procedure especially in patients with rheumatoid arthritis because the strain upon their hands is slight and the prostheses might therefore be expected to hold. If such alloplasty could be successful, it would be an ideal treatment since—as *Flatt* puts it—this combines the stability of arthrodesis with the mobility of arthroplasty.

In the Department of Hand Surgery of the Orthopaedic Hospital, Copenhagen, we have tried insertion of finger joint prostheses using the model and technique of *Flatt*.

MATERIAL AND METHODS

Our material is small and rather heterogeneous so that it cannot form the basis for a regular analysis. Brief case histories will be given and the experience which can be deduced from these cases will be discussed.

The operations were performed only upon the metacarpophalangeal joints of the index, middle, ring and little fingers on the indications listed by *Flatt*: (1) gross joint destruction, (2) palmar or ulnar dislocation of the joint, (3) ulnar drift com

CONCLUSIONS

Mechanical considerations indicate that a pulley mechanism which makes it possible for the finger to act like a normal finger will be obtained by placing the pulleys at the IP joints. This is only the case of course if the other necessary conditions are met. If it is important at the same time to retain complete extension this is the construction to aim at. If it is obvious that the muscle has lost some of its ability to contract and if active maximal flexion is held to be most important one has to consider whether to place both or one of the distal pulleys proximally of the IP joint. It will be difficult if not impossible to obtain full extension when full flexion is secured with this construction.

SUMMARY

Based on mathematical considerations it is concluded that from the mechanical point of view the most favourable position for each pulley of deep flexor tendons of fingers is at the interphalangeal joints. Physically best are broad and pliable pulleys.

RÉSUMÉ

En se basant sur des considérations mathématiques, il est conclu que d'un point de vue mécanique la position la plus favorable pour chaque «pulley» des tendons fléchisseurs profonds des doigts est l'articulation interphalangienne. Physiquement, les meilleures sont les «pulleys» larges et souples.

ZUSAMMENFASSUNG

Durch mathematische Betrachtung ist festgelegt, dass vom mechanischen Standpunkt aus die günstigste Stelle für jede „Pulley" der tiefen Flexorsehnen der Finger an den Interphalangealgelenken ist. Physikalish am besten sind breite und nachgiebige „Pulleys".

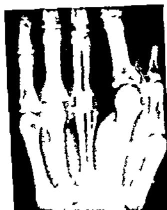


Figure 6



Figure 5



Figure 7

Figures 5, 6 and 7 Same patient as Figures 3 and 4
A Flatt prosthesis has been inserted



Figure 8



Figure 9

Figures 8 and 9 Same patient as Figures 3–7 2½ years after the operation
Now distinctly visible bone resorption around the prosthesis

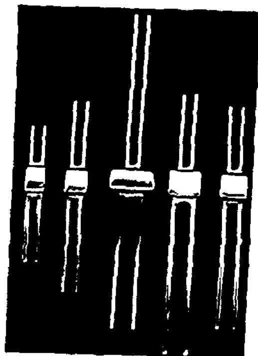


Figure 1 A finger joint prosthesis in the modification of Flatt (from Flatt The Care of the Rheumatoid Hand 1963)

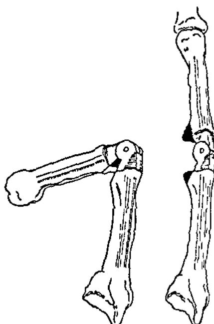


Figure 2 The position of the prosthesis illustrated schematically (from the same publication)

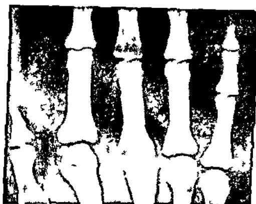


Figure 3



Figure 4

Figures 3 and 4 Destructions by old arthritis in the metacarpophalanged joint of the ring finger



Figure 12



Figure 13

Figures 12 and 13 Same patient as 10 and 11 A Flatt prosthesis has been inserted into the metacarpophalangeal joints of the index and long fingers and a Wainio arthroplasty has been done on the ring and little fingers

Case II (rec 234 64)

A woman aged 46 with rheumatoid arthritis of 2 years duration Never treated with cortisone Symptoms from both wrists and from the metacarpophalangeal joint of the right index finger Operation revealed severe destructions in this joint with much granulation tissue which showed microscopic evidence of rheumatoid arthritis A Flatt prosthesis was inserted without difficulty However as the resection had not included a sufficient portion of the volar corners of the bone flexion was somewhat restricted 170/130 The patient was relieved of pain immediately after the operation At follow up 9 months later she was fully satisfied with the result but X ray showed some bone resorption around the prosthesis At follow up 2 years after the operation the patient was still satisfied and free from pain function was good and objectively the mobility was unchanged However X ray showed slowly progressive bone resorption around the prosthesis

Case III (rec 78 432)

A man aged 46 with rapidly progressive rheumatoid arthritis of 9 years duration He was on cortisone medication His right hand which was most severely affected showed typical changes of the metacarpophalangeal joints with destruction dislocation and ulnar drift (Figure 10 11) Flatt prostheses were inserted with some difficulty into the metacarpophalangeal joints of the index and middle finger and the ring finger was treated by Wainio arthroplasty using the method which



Figure 10



Figure 11

Figures 10 and 11 Destruction and dislocation in the metacarpophalangeal joint because of rheumatoid arthritis

bined with joint destruction or palmar dislocation In addition the operation was carried out on patients with mono articular affections

Figures 1 and 2 are from Flatt s book The Care of the Rheumatoid Hand from 1963 They illustrate the type of prosthesis used and its position in schematic form

The operations are usually easy to perform through a transverse incision dorsally over the metacarpophalangeal joints A plaster cast is applied and left on for two weeks whereupon energetic training is started

CASE HISTORIES

Case I (1631/64)

A 44 year old woman with sequelae after long standing arthritis of the meta carphophalangeal joint of the ring finger (Figures 3 and 4) with pain and restricted mobility A Flatt prosthesis was inserted without difficulty but no mobility was obtained in the prosthesis so that one month later the screw was loosened The finger was rapidly trained and the patient was free from pain immediately after the operation (Figures 6 and 7) Six months later the result was good sub jectively as well as objectively including the X ray appearances Two and a half years after the operation the result was still good clinically but X rays now showed definite bone resorption around the prosthesis (Figures 8 and 9)



Figure 18



Figure 19

Figures 18 and 19 Severe deformities in the metacarpophalangeal joints because of rheumatoid arthritis

Flatt described in 1963 (Figures 12 13) Infection developed in the index finger and the prosthesis in this site had to be removed 6 months after the operation In the 3rd finger the prosthesis was working well The patient was relieved of pain immediately after the operation and the training was fairly easy At follow up 2 years after the operation the patient was fully satisfied with the result and objectively too the result was good The ulnar drift was abolished and the metacarpophalangeal joints on the long ring and little fingers could be moved 150/115 Comparison of the joints with Flatt prostheses and those with Wainio arthroplasty showed active flexion to be the same while active extension was somewhat poorer in the prosthesis joint than in the Wainio joints but the stability was better in the prosthesis joint The second metacarpophalangeal joint in which the Flatt prosthesis had been removed was ankylosed in the position of function X ray revealed resorption around the prosthesis (Figures 14 15) Four years after the operation the patient was still fully satisfied, free from pain and function was unchanged but X ray showed progressive bone resorption around the prosthesis (Figures 16 and 17)

Case II (rec 8413 63)

A man aged 6 with rheumatoid arthritis of long duration involving nearly all joints with very severe deformities of the hands with extensive destructions and dislocation in the metacarpophalangeal joints (Figures 18 19) Prolonged, intensive cortisone therapy Flatt prostheses were inserted into the metacarpophalangeal joints of the index and the little finger and Wainio arthroplasty was done on the middle and ring fingers of one hand (Figures 0 21) The immediate result was good with relief of pain and improved function At follow up 1 year after the operation the patient was very pleased with the result. For instance he could lift



Figure 14



Figure 15

Figures 14 and 15 Same patients as Figures 10–13 two years after the operation The prosthesis in the metacarpophanlangeal joint of the index finger has been removed because of infection and there is definite bone resorption around the prosthesis in the ring finger with penetration of the cortex



Figure 16



Figure 17

Figures 16 and 17 Same patient as 10–15 four years after the operation There has been only slight progression of the bone resorption around the prosthesis



Figure 22



Figure 23

Figures 22 and 23 Same patient as 18-21 one year after the operation Pronounced bone resorption around the prostheses with penetration of the cortex

and training was started but in one month swelling and tenderness appeared at the site of the metacarpophalangeal joint of the index finger However this reaction responded to penicillin therapy Six months after the operation the patient was still free from pain but function was poor and X ray showed bone resorption around the prostheses The patient has failed to appear for continued follow up in spite of repeated requests

Case 11 (rec 59457)

A woman aged 63 with a long history of rheumatoid arthritis involving many joints Repeated courses of cortisone therapy Owing to destruction and dislocation in the metacarpophalangeal joints a Flatt prosthesis was inserted into the index finger and Walinorthroplasty was done on the long ring and little fingers It proved rather difficult to train the fingers At follow up 6 months later the patient reported tenderness of the metacarpophalangeal joint of the index finger when she used it but otherwise the joint was practically free from pain Mobility was 170 10 and X ray showed some bone resorption around the prosthesis At follow up one year after the operation the clinical result was still quite good but on the X ray film the absorption around the prosthesis was found to have slowly progressed

DISCUSSION

Thus 6 patients had 11 Flatt prostheses inserted In one case the prosthesis had to be removed because of infection while in another case of infection the symptoms yielded to penicillin The patients on cortisone therapy because of rheumatoid arthritis showed radiological



Figure 20



Figure 21

Figures 20 and 21 Same patient as 18–19 Flatt prostheses have been inserted in the metacarpophalangeal joints of the index and little fingers Waino arthroplasty has been done on the long finger and ring finger

a cup which he had not been able to do for many years and he asked to have a similar operation done on the other hand Objectively the result was also satisfactory considering how severely affected the hand had been before the operation The patient could clench the hand fairly tightly He could extend the fingers normally in the proximal and distal interphalangeal joints the extension was 130 in the metacarpophalangeal joints of the index and little finger (with the prostheses) and 170 in the middle finger and the ring finger (treated by Waino arthroplasty) However X ray showed bone resorption around the prostheses especially in the little finger with penetration of the cortex (Figures 22-23) At follow up 2½ years after the operation the patient was still pleased with the hand mobility was unchanged but X ray showed progressive resorption around the prostheses The other hand had been treated by the same procedure but this hand proved very difficult to train and at follow up 18 months after the operation the result was unsatisfactory True the patient had been relieved of pain but function was poor with no active mobility in the metacarpophalangeal joints neither in those treated by prostheses nor in those treated by arthroplasty X rays showed no bone absorption around the prostheses presumably because they had not been moved

Case V (rec 16861/62)

A woman aged 54 with a long history of severe rheumatoid arthritis treated for a long time with cortisone Owing to severe changes in the hands with destructions and dislocations in the metacarpophalangeal joints Flatt prostheses were inserted into the index and little fingers and Waino arthroplasty was done on the long and ring fingers The immediate result was good the patient was relieved of pain

CONCLUSION

Endoprostheses inserted into finger joints give good primary results—relief of pain and good function—when inserted into traumatized or rheumatoid joints The main complication is bone resorption around the prosthesis with subsequent looseness This complication is most common in patients with rheumatoid arhritis especially if they are on cortisone The method must therefore be reserved for old patients with pain and severe deformities in whom it is important to obtain relief from pain and improved function even though the result can be maintained for only a few years If a means of fixing the prosthesis better can be found the indications might be extended

SUMMARY

Flatt finger joint prostheses were inserted into 11 joints of 6 patients Infection occurred around 2 one of which had to be removed All the patients were relieved of pain immediately after the operation and function was good in all but one The main complication was radiologically demonstrable bone resorption around the prostheses with subsequent looseness This absorption appeared earliest in rheumatoid patients on cortisone It is pointed out that in its present form the method can be used only for old patients with pain and severe deformities If a better fixation method should be found the indications might be extended

RÉSUMÉ

Des prothèses Flatt des articulations des doigts ont été insérées dans 11 articulations chez 6 malades Une infection s est produite dans deux cas il a fallu retirer la prothèse dans l un de ces cas Tous les malades ont été soulagés de leurs douleurs immédiatement après l operation et la fonction a été bonne sauf dans un cas La complication principale est l absorption osseuse démontrable radiologiquement autour de la prothès d ou il résulte un certain relâchement Cette absorption apparaît très tôt chez les malades rhumatisants traités au cortisone Il est souligné que dans sa présente forme cette méthode est seulement applicable aux malades âgés ayant des douleurs et de graves déformités S il est possible de trouver une meilleure méthode de fixation l indication pourra être étendue

signs of bone resorption around the prostheses as early as 6 months after the operation except in the case of 2 prostheses where no mobility had been obtained The best result was obtained in the patient who did not have rheumatoid arthritis, and who had also not received cortisone But now—2½ years after the operation—X ray showed bone absorption around the prosthesis in this case too

Brannon (1959) used his prosthesis in traumatic cases Like others he found bone resorption, with consequent loosening of the prosthesis *to be the main complication He tried to obtain better fixation by a* couple of staples but the follow up in those cases was not long enough to allow assessment of the late results

Flatt inserted his prostheses into a large number of patients with rheumatoid arthritis In his paper from 1963, his material had increased to 140 patients His results are striking and he has very few complications True he *has* observed bone resorption around some of the prostheses but he does not attach any major importance to it According to Flatt this complication is more common among patients who do not have rheumatoid arthritis, because they use their hands *more This is at variance with the observations made in the present* material, in which the bone resorption appeared earliest in the rheumatoid patients especially those on cortisone It is likely that cortisone *promotes this bone resorption*

In other words the use of endoprostheses in the finger joints involves considerable complications Apart from infection *Flatt* (1963) mentioned sloughing of the overlying soft tissues and various technical errors In the present author s opinion by far the most serious complication is the inevitable bone resorption which must be interpreted as the precursor of loosening of the prosthesis All these complications might lead one to abandon the procedure entirely It is a fact however that the patients are relieved of pain after the operation that the training is relatively easy and need not be long that function becomes good and that these gains will persist for up to 4 years after the operation in spite of radiological evidence of bone resorption around the prostheses With the present technique the method must be reserved for old patients with pain and severe deformities

If the Flatt prostheses are to be used for wider indications they have to be fixed better As already mentioned Brannon tried staples but the prostheses might possibly be fixed with acryl cement such as the McKee Ferard prosthesis in the hip But the experience with the Judet prostheses argues one somewhat hesitant in using acryl

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From the Ortopaedic Hospital of the Invalid Foundation
(Head Professor A Langenskiold M D) Helsinki Finland

OSTEOSYNTHESIS WITH A THICK MEDULLARY NAIL IN NON UNION OF LONG BONES

By

L E LAURENT & A LANGENSKIOLD

Received 20 ii 67

The results of treatment of pseudarthroses at the Orthopaedic Hospital of the Invalid Foundation during the period 1945–1960 have been reported by *Kivilaakso & Saarialho* (1963) The series consisted of 160 patients and healing was achieved in 87 per cent of cases At the Sicot congress in 1960 large series were presented by *Boyd Lipinski & Wiley* (812 cases) and by *Merle d Aubigné & Cauchoix* (814 cases) The results in these series were excellent healing being achieved in 94 per cent of the cases

Although we obtained satisfactory results with our earlier method of treating pseudarthrosis in which onlay or inlay graft and z resection were employed in the majority of cases it seemed justifiable to try a method which permitted earlier mobilization When the patients were sent to this hospital for treatment several unsuccessful operations had often been carried out the injured extremity had *not been subjected* to weight bearing and the patients had been incapable of work for several year Owing to earlier immobilization there was often severe stiffness in the joints on either side of the pseudarthrosis and marked osteoporosis It *therefore seemed* important to try a method in which external fixation could be avoided if possible and in which early weightbearing by the limb could be permitted Reaming of the medullary cavity and fixation with a *thick medullary* nail according to *Kuntscher* seemed to fulfil these requirements We have therefore been using this method since 1964

Good results from the treatment of pseudarthrosis with medullary nails without reaming of the *medullary* cavity usually combined with free bone grafts have been reported by *Merle d Aubigné Mal en Lot*

ZUSAMMENFASSUNG

Flatt's Fingergelenksprothesen wurden in 11 Gelenken von 6 Patienten angebracht. Infektion entstand bei zweien davon, von denen eine entfernt werden musste. Alle Patienten waren von ihren Schmerzen unmittelbar nach der Operation befreit, und die Funktion war bei allen abgesehen von einem gut. Die Hauptkomplikation war röntgenologisch nachweisbare Knochen absorption um die Prothese mit nachfolgender Lockerung. Diese Absorption zeigte sich am frühesten bei Patienten, die Cortison Medikation erhielten. Man hebt hervor, dass die Methode zur Zeit nur bei alten Patienten mit Schmerzen und schweren Deformiteten verwendbar ist. Wenn eine bessere Fixationsmethode gefunden wird, kann die Anzeigestellung erweitert werden.

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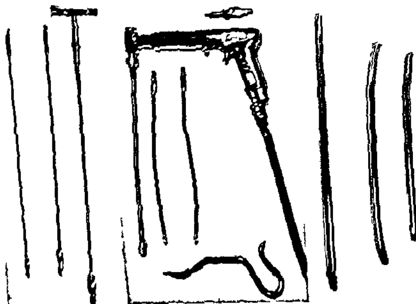


Figure 1 The reamers the pneumatic drill and medullary nails used for osteosynthesis

MATFRIAL

The serie c nsi ts of 3o patients treated during the period 1964 1966 The age of the patients is given in Table 1

The site of the p eu larthrosis and s me particulars of the nature of the injuries an l e rlier treatment are presented in Table 2

There was a c mplicated fracture in 11 ca es Primary surgical fixation had been c rried ut in 15 cases The fracture had been fixed with an ordinary Kuntscher me l llary nail *in 7 ca es with a Rush* pin in 3 ca es with a Lane s plate in 4 c es n l by m ns of a wire loop in 1 case Operation for pseudarthrosis had previ u ly l een carrie l out on 16 *patients* the number of operations involved being 26 Operation f r osteitis before oste synthesis was carried out six times Skin grafting was perf rme l *pre peratively in* three c ses The average interval between fr tu and o teo ynthesis was 25 months

OI ERATIVF TECHNIQUF

The instruments used for the operation can be seen in Figure 1

I or reaming the medull iry cavity we have since 1965 used a pneu matic AOI drill which has functioned to our satisfaction The diameter of the burrs increases by 0.5 mm per burr which has proved adequate

tes, and *Palmer*, among others. A number of other workers besides *Kuntscher* have reported good results from the medullary nailing of pseudarthroses with thick nails including *Merle d Aubigne, Bohler, Herzog, Muller, Salem* and *v. Hellens et al.*

The following principles were adopted in the treatment of patients with pseudarthrosis before osteosynthesis was performed.

If osteitis or fistulae are present, excision and sequestrectomy are carried out. We usually wait half a year after the fistulae have closed before we perform the osteosynthesis.

If, owing to scarred or poorly vascularized skin, there appears to be any risk of infection or skin necrosis in connection with osteosynthesis, excision of cicatricial tissue and free or pedicle grafting are carried out.

Stiff joints are mobilized by means of physiotherapy and when necessary by manipulation under anaesthesia. In the knee we aim at achieving full range of flexion before operation if possible.

Osteoporosis is counteracted by permitting the patient to use the injured limb, if necessary with the aid of a supporting bandage. This requires special supervision by the attending surgeon since the patient is afraid to place any weight on the pseudarthrosis.

Table 1. Age of the patients at operation

Age	Under 20	20–29	30–39	40–49	50–59	Over 60
Number	3	4	7	12	5	4

Table 2. Nature of the material

Location of non union	Tibia	Femur	Humerus	Radius or Ulna	Total
Number of patients	17	12	4	2	35
Open fracture	8	–	2	1	11
Primary open reduction	6	8	1	–	15
Osteitis	3	1	1	1	6
Previous operations for non union					
One operation	4	3	2	–	9
Two operations	1	2	1	1	5
Three or more	1	–	1	–	2
Average time between fracture and nailing in months	27	26	37	24	

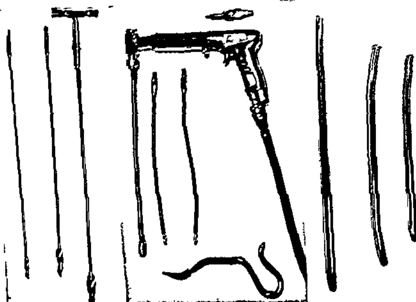


Figure 1 The reamers the pneumatic drill and medullary nails used for osteosynthesis

MATERIAL

The series consists of 3 patients treated during the period 1964–1966 The age of the patients is given in Table 1

The site of the pseudarthrosis and some particulars of the nature of the injuries and earlier treatment are presented in Table 2

There was a complicated fracture in 11 cases Primary surgical f xation had been carried out in 15 cases The fracture had been fixed with an ord nary Kuntscher medulla y nail in 7 cases with a Rush p n in 3 cases w th a Lane s plate in 4 cases and by means of a wire l op in 1 case Operation for pseudarthrosis had previ ously been carried out on 16 patients the number of operat ons involved being 26 Operation for osteit s before osteosynthesis was carried out six times Skin grafting was performed preoperatively in three cases The average interval between fr cture and o teo ynthesis was 28 months

OPERATIVE TECHNIQUE

The instruments used for the operation can be seen in Figure 1

For reaming the medullary cavity we have since 1965 used a pneu matic AOI drill which has functioned to our satisfaction The diameter of the burrs increases by 0 5 mm per burr which has proved adequate

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Average time between fracture and nailing in months	27	26	37	24	

nailing was carried out in three cases infection flared up in one of these but the pseudarthrosis fused One of the advantages of the method is that the pseudarthrosis heals despite infection provided the nail is not removed too soon Fairly long courses of treatment with antibiotics were of course necessary in infected cases In two cases of pseudarthrosis with a defect and in which transplantation with a tibial graft was carried out skin necrosis occurred In these cases free skin grafting was employed the necrosed area being excised 2 to 3 weeks after the operation It is our opinion that early skin grafting in these cases played a decisive role in the results

In pseudarthrosis of the tibia the diameter of the nail was 10 to 16 mm In two cases the nail pierced the posterior cortex and had to be bent forwards at its distal end in order to enter the distal fragment This was done at the metal workshop of the hospital since nails of more than 11 mm thickness cannot be bent without special instruments Nails were also shortened when necessary at the workshop

Postoperative Treatment

Eight patients were treated without external fixation Nine patients were supplied with a walking plaster cast for 6 weeks *The plaster* cast was as a rule applied 2 weeks after operation when the wound *had healed* Since there is a risk of infection and necrosis of *the skin* it is important that the incision can be inspected before application of a walking plaster cast Weight bearing was as a rule *permitted* 3 *to* 4 weeks after the operation

Healing required an average of about 5 months in cases of pseudarthrosis of the tibia The patients soon regained preoperative mobility in the knee and talocrural joints

Figure 2 shows the result in a case of pseudarthrosis of the tibia with a defect

FEMUR

The operative method and the results are given in Table 4

Consolidation was achieved *in* all 12 cases The average time required for healing was 6 months There was infection in 2 cases A free bone graft from the iliac crest or the tibia was used *in four* cases and fixed with screws while cancellous bone from the iliac crest was used *in* three cases

The diameter of the nail was 11 to 16 mm the usual size *being* 14

The type of drill we used earlier had a diameter increase of 1 mm per burr, which proved too much The drill became hot and stuck We have principally used Zimmer s medullary nails The tibial nail is bent at the proximal end (*Herzog*) The operative technique has been described by *Kuntscher* (1962) and by *Muller, Allgower & Willenegger* (1965) among others

In three cases of pseudarthrosis of the tibia closed nailing was carried out while in all other cases the pseudarthrosis was exposed An X ray television, which no doubt greatly facilitates closed nailing was not available However polaroid radiograms which can be obtained in some minutes were of great help

In pseudarthrosis with a defect in case in which the nail did not seem to prevent rotation entirely and in cases in which the pseudarthrosis was situated comparatively near the joint the operation was supplemented with a free transplant In 11 cases, bone from the tibia or the iliac crest was transplanted and fixed with screws as an onlay graft In a further six cases cancellous bone from the iliac crest or from the tibia was transplanted to the site of the pseudarthrosis In order to prevent any reduction of the osteogenic capacity of the graft the transplants were not allowed to dry even momentarily (*Puranen* 1966)

TIBIA

The operative method and the results are given in Table 3

Table 3 Tibia

Method	Number of cases	Union	Flare up of infection	Failure
Nail+graft from tibia or the iliac crest	4	4	3	–
Nail+cancellous bone	3	2	2	1
Nail alone	7	7	2	–
Closed nailing	3	3	1	–
Total	17	16	8	1

Osteotomy of the fibula was carried out in 7 cases As will be seen from the table healing was achieved in 16 cases Infection and osteitis spoiled the result in one case and the nail had to be removed The number of infections was large 8 cases Seven of these had previously been infected Despite infection healing took place in 7 cases Closed

mm The nail penetrated the knee joint in two cases In one of these the nail was exchanged a shorter nail being substituted and fixed proximally with a screw In the second case we did not consider an exchange of the nail necessary In this case the knee was stiff after a pathological fracture and there was a pseudarthrosis in the lower end of the femur as a result of myxosarcoma for which had been given X ray treatment It had previously been operated on four times

Table 4 Femur

Method	Number of cases	Union	Flare up of infection
Nail+graft from tibia or the iliac crest	4	4	1
Nail+cancellous bone	3	3	–
Nail alone	5	5	1
Total	12	12	2

Eleven patients were mobilized on the first postoperative day with the aid of crutches and exercise of the knee and hip joints was immediately commenced One patient was given a hip walking plaster for six weeks

In pseudarthrosis of the femur not too close to a joint this method seems superior to all other ones

The result in a case of pseudarthrosis of the femur is shown in Figure 3

Table 5 Humerus

Method	Number of cases	Union	Flare up of infection	Failure
Nail+graft from the iliac crest	1	1	–	–
Nail alone	3	–	1	3
Total	4	1	1	3

HUMERUS

The operative method and the results of treatment in four cases of pseudarthrosis of the humerus are given in Table 5

The diameter of the nail was 11 to 14 mm Consolidation was only achieved in one case in which rotation between the fragments was



Figure 2 A. Non union of the tibia with a defect of the diaphysis two and a half years after an open and infected fracture. Male age 19 years.

B. Side view radiograph five months after medullary nailing and transplantation of a free graft from the other tibia.

C. Solid union eleven months after operation.

prevented by means of a graft from the iliac crest fixed with screws (Figure 4) In one of the cases an old infection was activated and the nail worked loose In the two remaining cases the nail did not prevent rotation between the fragments resorption occurred and healing did not take place All the patients had trouble in mobilizing the shoulder joint owing to irritation by the proximal end of the nail A thoraco-brachial plaster cast was applied in one case

Thus in pseudarthrosis *of the humerus our experience of the method* is not good If this method is used a graft fixed with screws must evidently always be applied *Merle d Aubigne & Cauchoix* report good results with this method in 99 per cent of 90 cases If the nail is introduced at the greater tuberosity there is invariably in our experience irritation and reduced mobility in the shoulder joint

RADIUS AND ULNA

The operative method and the results in two cases of pseudarthrosis of the radius and ulna respectively are seen in Table 6

Table 6 Radius o Ulna

Method	Number of cases	Union
Nail+graft from the iliac crest	2	2

At operation on the pseudarthrosis of the radius the ulnar head was removed while in pseudarthrosis of the ulna the head of the radius was removed According to our earlier experience of treatment of pseudarthrosis of a bone of the forearm it is always rewarding to carry out such a resection to prevent rotation stress of the osteosynthesis

The diameter of the nail in these cases was 6 mm The medullary cavity was reamed with a hand drill The pseudarthrosis was moreover stabilized with a graft from the iliac crest which was fixed by two screws A plaster cast was applied and kept in place for two months which was probably unnecessary Both pseudarthroses were consolidated after 3½ months Figure 3 shows the case of pseudarthrosis of the radius



Figure 3 A Non union of the femur after nailing with an ordinary Küntscher nail eleven months earlier Male age 27 years

B Condition eleven months after medullary nailing with a nail of fourteen millimeters thickness

C Side view corresponding to B

prevented by means of a graft from the iliac crest fixed with screws (Figure 4) In one of the cases an old infection was activated and the nail worked loose In the two remaining cases the nail did not prevent rotation between the fragments resorption occurred and healing did not take place All the patients had trouble in mobilizing the shoulder joint *owing to irritation by* the proximal end of the nail A thoraco brachial plaster cast was applied in one case

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RADIUS AND ULNA

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Table 6 Radius or Ulna

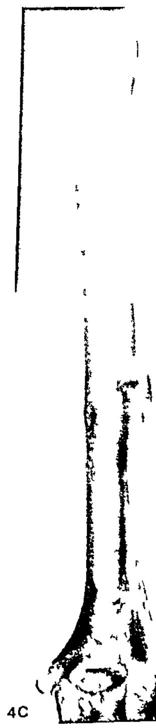
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Nail+graft from the iliac crest	2	2

At operation on the pseudarthrosis of the radius the ulnar head was removed while in pseudarthrosis of the ulna the head of the radius was removed According to our earlier experience of treatment of pseudarthrosis of a bone of the forearm it is always rewarding to carry out such a resection to prevent rotation stress of the osteosynthesis

The diameter of the nail in these cases was 6 mm The medullary cavity was reamed with a hand drill The pseudarthrosis was moreover stabilized with a graft from the iliac crest *which was fixed by two* screws A plaster cast was applied and kept in place for two months which was probably unnecessary Both pseudarthroses were consolidated after 3½ months Figure 3 shows the case of pseudarthrosis of the radius


4A


4B


4C

DISCUSSION

The results in all cases can be seen in Table 7

Healing was achieved in 31 cases while 4 failed 2 of them owing to infection and 2 which were cases of pseudarthrosis of the humerus because the nail did not prevent rotation between the fragments The number of cases in which infection flared up was large 10 cases In one case primary infection occurred at the operation carried out for pseudarthrosis

Table 7 Results of medullary nailing in 35 cases of non union

Location	Number of cases	Union	Flare up of infection	Failure
Tibia	17	16	8	1
Femur	12	12	2	–
Humerus	4	1	1	3
Radius or Ulna	2	2	–	–
Total	35	31	11	4

In *pseudarthrosis of the tibia* the greatest advantage of the method is that owing to the rigid fixation weight bearing of the limb can be permitted at an early stage Mobilization of the knee and talocrural joints may likewise be commenced early In this way osteoporosis is counteracted and bony union is achieved more rapidly According to *Anderson* endosteal bone formation ceases at medullary nailing and union takes place periosteally and from the ends of the bone The time required for healing after nailing is not always easy to estimate but the method does not seem to require a longer time than other methods One drawback is the risk of flare up of infection (*Macausland & Eaton*) which is particularly high in pseudarthrosis of the tibia In

Figure 4 A Non union of the humerus primarily nailed with a Rush pin four years earlier Male age 44 years Two years after injury the Rush pin was replaced by a thin Küntscher nail which is seen broken in the picture

B The humerus nine months after nailing with a nail of eleven millimeters thick ness and transplantation of a free graft from the ilium The nail is loose and has moved cranially

C The same humerus one-and-a-half years after the last nailing The nail has been removed



Figure 5 A. Non-union of the radius after fracture one year earlier. Male, age 53 years.

the present series this was due to earlier infection as a result of open fracture, cicatrices and poorly vascularized soft parts. In most of our cases, however, union took place despite flare up of infection, which is not, as a rule, the case when other methods are employed. The site of latent infection can be obviated by osteosynthesis with a free graft between the tibia and the fibula by means of lateral incisions (*Merle d'Aubigné*, and others). Of course, this method requires prolonged immobilization in a plaster cast. In pseudarthrosis with a defect, tibio

Figure 5 B and C The same forearm three months after nailing of the radius with a nail of six millimeters thickness and transplantation of a free graft from the ilium The graft was fixed with screws The capitulum of the ulna was removed at the same operation



fibular osteosynthesis can be employed with good results (*Laurent*, and others)

At closed nailing there is less risk of infection but in most cases malposition must be corrected at open operation and if the pseudarthrosis is situated in the lower portion of the tibia a graft must be added in order to prevent rotation That infection may occur even at closed nailing is demonstrated by one of our cases and has also been mentioned by *Muller et al* and *Bohler* By nailing of pseudar

throsis of the tibia in most cases by closed nailing *Herzog* achieved healing in 57 out of 59 cases and Böhler in all of 40 cases We have no experience of preoperative reduction of the pseudarthrosis by means of extension treatment or transverse osteotomy according to *Küntscher* At closed nailing an X ray television considerably facilitates the operation, as was also pointed out by *Böhler*

In our earlier series onlay grafts gave good results (*Kivilaakso & Saarialho*) but this method required immobilization in a plaster cast for a minimum of 4 months Because of the stable fixation achieved with the medullary nail we intend to continue using this method in suitable cases

In *pseudarthrosis of the shaft of the femur* this procedure seems to be the method of choice a fact also pointed out by *Boyd et al*, *Merle d'Aubigné et al*, *Müller et al*, and others External fixation with plaster casts can then usually be avoided which means that mobilization of the patient and the joints on either side of the pseudarthrosis can be commenced immediately after the operation At pseudarthrosis of the femur in particular there is often stiffness of the knee joint following some earlier treatment A method that permits immediate postoperative mobilization of the knee is of great value The frequency of thrombosis is also reduced There was no case of thrombosis in the present series The femur is moreover easier to nail than the tibia If owing to the situation of the pseudarthrosis there is a risk of rotation between the fragments a free transplant should be added and fixed with screws

In *pseudarthrosis of the humerus* our results were poor partly because a free graft to prevent rotation was applied in one case only In one case there had repeatedly been osteitis and infection spoiled the result Carcinoma of the liver was later diagnosed in another case and this had probably impaired healing However the nail does not seem to provide rigid fixation in the humerus and immobilization in a plaster cast for a short period may be necessary (*Merle d'Aubigné et al*) Stiffness of the shoulder joint owing to irritation by the head of the nail constitutes a considerable disadvantage and occurred in all our cases It is probably that the AOI compression plate can provide rigid fixation in pseudarthrosis of the humerus and may thus constitute a better method (*Müller et al*) Good results in pseudarthrosis of the humerus have been reported by *Hindmarsh & Unander Scharin* who used Egger's plate and cancellous bone This method required a plaster cast for 4 months In our earlier series we obtained good results with

z resection in pseudarthrosis of the humerus This method likewise required a thoracobrachial plaster cast at least 4 months Now we use medullary nailing in pseudarthrosis of the humerus in selected cases only

In *pseudarthrosis of the radius or ulna* nailing is useful as an alternative to other methods Our two cases do not allow of any further conclusions *Boyd et al* recommend medullary nailing particularly in pseudarthrosis of the ulna It is possible that the AOI compression plate constitutes a better method for the treatment of pseudarthrosis of the radial or ulnar diaphysis and permits after treatment without external fixation

Medullary nailing is not a simple procedure and makes heavy demands on the surgeon s skill Reaming of the medullary cavity with a pneumatic drill renders the operation easier however while at the same time rigid fixation can as a rule be achieved Nails of the correct length and calibre must be available Upon correct indications and with a good operative technique this method gives good results in pseudarthrosis of the diaphysis of long bones Risk of infection must be reckoned with and a free bone graft should be added if the healing conditions s em poor or the fixation uncertain Since in many cases it is possible to dispense with plaster casts the after treatment is considerably facilitated from the point of view both of the patient and of the surgeon

SUMMARY

The material consists of 35 cases of non union of the shaft of long bones treated at the Orthopaedic Hospital of the Invalid Foundation with a thick medullary nail The non union was located in 17 cases in the tibia in 12 cases in the femur in 4 cases in the humerus and in 2 cases in the radius and ulna respectively The diameter of the nail was 10 16 mm in the case of non union of the tibia in non union of the femur 11 16 mm of the humerus 11–14 mm and of the radius and ulna 6 mm Open reduction was carried out in all cases except in three of non union of the tibia where closed nailing was performed In 17 cases the osteosynthesis was completed with the application of an autogeneous free graft of bone or cancellous bone The commonest complication was flare up of infection which occurred in 10 cases In 9 cases consolidation was achieved despite the infection The method seems to be very suitable in cases of non union of the shaft of the

femur and the tibia, permitting mobilization and weight bearing very soon after operation. The method was less suitable in the case of non-union of the humerus because the nail loosened and the head of the nail caused irritation and stiffness of the shoulder joint. Sound union was achieved in all cases of non-union of the femur and in 16 of the 17 cases of non-union of the tibia.

RÉSUMÉ

Les observations portent sur 35 cas de non-soudure du corps d'os longs traités à l'Hôpital Orthopédique de la Fondation des Invalides au moyen d'un épais clou médullaire. Dans 17 cas la non-soudure était localisée dans le tibia, dans 12 dans le fémur, dans 4 dans l'humérus et dans 2 cas dans le radius et le cubitus respectivement. Le diamètre du clou était de 10–16 mm dans les cas de non-soudure du tibia, de 11–16 mm dans ceux du fémur, de 11–14 mm dans ceux de l'humérus et de 6 mm dans ceux du radius et du cubitus. Une réduction ouverte a été pratiquée dans les cas de non-soudure du tibia, excepté pour trois dans lesquels un enclouage fermé a été réalisé. Dans 17 cas l'ostéosynthèse a été complétée par une greffe autogène d'os spongieux. La complication la plus courante a été l'apparition d'une infection constatée dans 10 cas. Dans 9 cas la soudure s'est effectuée malgré l'infection. La méthode semble convenir parfaitement dans les cas de non-soudure du corps du fémur et du tibia; elle permet la mobilisation et le support du poids du corps très rapidement après l'opération. La méthode convient moins bien dans le cas de non-soudure de l'humérus parce que le clou ne reste pas fixé et que la tête du clou peut causer une irritation et une rigidité de l'articulation de l'épaule. Une soudure saine a été réalisée dans tous les cas de non-soudure du fémur et dans 16 des 17 cas de non-soudure du tibia.

ZUSAMMENFASSUNG

Das Material umfasst 35 Fälle von Pseudarthrose der langen Röhrenknochen, die im Orthopädischen Krankenhaus der Invalidenstiftung mit einem dicken Marknagel behandelt wurden. Siebzehn Pseudarthrosen der Tibia, zwölf des Femurs, vier des Humerus, eine der Ulna und eine des Radius wurden genagelt. Der Durchmesser der Nägel, die bei Tibiapseudarthrosen angewandt wurden, war 10–16 mm, bei Femurpseudarthrosen war er 11–16 mm, bei Humeruspseudarthrosen 11–14

mm und bei Pseudarthrosen der Ulna und des Radius 6 mm Eine offene Reduktion wurde in allen Fällen mit Ausnahme von drei Fällen von Tibiapseudarthrose gemacht In den drei Fallen wurde eine ge schlossene Nagelung ausgefuhrt In siebzehn Fallen wurde die Osteo synthese mit der Applikation eines autogenen Knochentransplantates kombiniert Die gewohnlichste Komplikation war ein Aufflackern einer alten Infektion was in zehn Fallen auftrat In neun Fallen wurde eine Konsolidation trotz einer Infektion erreicht Die Methode scheint für die Behandlung von Pseudarthrosen der Diaphysen des Femurs und der Tibia gut geeignet zu sein und erlaubt fruhzeitige Mobilisation und Belastung Fur das Humerus ist die Methode weniger geeignet da Lockerung des Nagels und Irritation und Versteifung des Schulter gelenks gesehen wurde Knocherne Heilung wurde bei allen Fallen von Femurpseudarthrose und in 16 von 17 Tibiapseudarthrosen erreicht

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COMPRESSION ARTHRODESIS OF THE HIP JOINT BY THE METHOD OF AXER

A preliminary Report

By

A LANGENSKIÖLD & L E LAURENT

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For unilateral severe affections of the hip joint arthrodesis is still the only treatment which guarantees a stable hip free of pain for the rest of the patient s life In osteoarthritis intertrochanteric osteotomy with internal fixation and combined with discission of the iliopsoas tendon has given excellent results This has considerably reduced the number of cases in which arthrodesis of the hip is found indicated There are however cases in which extreme deformity and limitation of motion make osteotomy ineffective Our experience from cup arthroplasty and the use of acrylic endoprostheses in such cases have not been encouraging as only about fifty per cent of the patients benefited from the operation (*Laurent*) The results obtained by total replacement of the hip joint by a double endoprosthesis (*Charnley McKee & Watson Farrar*) cannot yet be judged

Immobilization in a plaster spica for several weeks with the risk of complications from prolonged bed rest and a comparatively high incidence of fibrous union are disadvantages of many methods used for arthrodesis of the hip As a good mobility of the knee joint is of paramount importance for a person with a stiff hip arthrodesis of the hip should not imply a risk of stiffening of the knee

For arthrodesis of the hip joint we have been looking for a method allowing early mobilization and weight bearing of the limb without too great a risk of pseudarthrosis

Watson Jones & Robinson obtained fusion in ninety four per cent of 120 cases in which Smith Petersen s nail was used for intraarticular arthrodesis of the hip However the patients were immobilized in

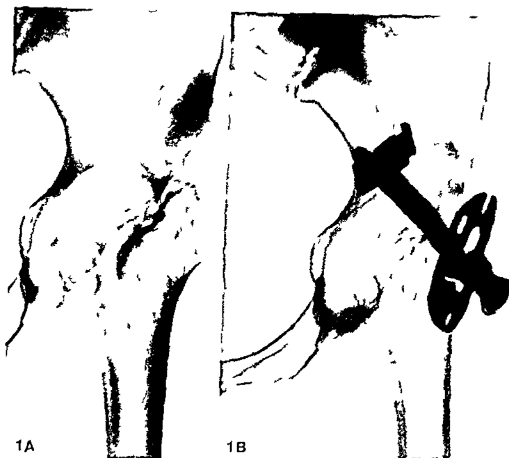


Figure 1 A Tuberculosis of the left hip Female age 32 years The femoral head and neck were missing There was an active focus in the lesser trochanter which was evacuated at the operation
B Iliotrochanteric fusion nine months after operation

plaster for four months With a similar method *Lindstrom* obtained consolidation in thirty eight cases out of forty without external fixation in plaster Our own results with this method have been less encouraging *Alvik* obtained good results in forty one cases in which internal fixation was performed by means of a Smith Petersen nail and a metal plate fixed with screws

Other methods for internal fixation in arthrodesis of the hip have been described by *Niebauer, Dickson & Willien DePalma et al, Witt, May & Mauck Altcheek* and *Onji et al Graziati & Kalen* showed in experiments that three Nystrom nails gave a more stable fixation of the hip than one Smith Petersen nail *Merle d Aubigne & Deburge* and *Smith & Baab* have used fixation by three Vitallium nails

In 1955 *Charnley* described his method of central dislocation of the

hip The method was later developed by him to include the use of a compression screw (*Morris* 1966) *McKee* (19J7) got good results in forty seven cases out of fifty using a lag screw in combination with a bone graft from the greater trochanter The method of *Chryssantakis* who used a Smith Petersen nail in combination with a screw was used by us in a few cases with a good result

In 1961 *Axer* described a new method for compression arthrodesis of the hip joint and reported his experience obtained in nineteen cases Wishing to try a method allowing early mobilization we have used *Axer*s method in thirteen cases since the spring of 196J

MATERIAL

Five of the patients were males and eight were females The age of the patients appears in Table 1

Table 1

Age of the patients at operation					
Age	20–29	30–39	40 49	50–59	60–69
Number of patients	1	5	2	3	2

Caus of the deformity of the hip		
Tuberculosis	3 cases	(active process in one)
Acute coxitis	2 ases	
Trauma	4 cases	(in two fracture of the femoral neck in one traumatic d sloca tion in one a war injury)
Prima y o te arthritis	3 cases	
Infant l c xa va a	1 case	

In twelve ases the contralateral hip was normal in one case there was slight ste arth it s in the ther hip All patients had pain from weight bearing eight of th m had pa n when esting Eleven patients were limping con iderably but did n t need a can One was u ing a cane and one patient walked with crutches There was malp it n of the hip n five cases and shortening of the limb in twelve

Th rang of flexion mo ement of the hip joint was less than ten degrees in ix c ten t thirty degree in five and thirty to sixty in two ca es The range f movement of the knee jo nt was normal in ten ca es and in three it was from a po it n of n n ty degree to ne of 180 degrees

In th adi g aph s ver deformity of the j int with the head of the femur rem ining w e n in six c es In five case the head of the femur had partly llaps d nd in two ca e the head was missing altogether Denervation of the hip had b en carri d out in two c se in two o teotomy for correction of posit n

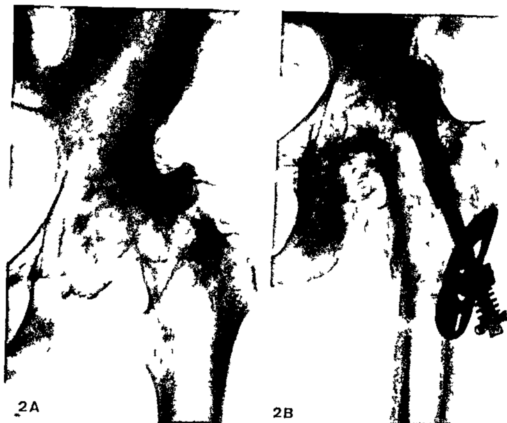


Figure 2 A Osteoarthritis of the left hip Female age 55 years
B Bony fusion of the hip eleven months after arthrodesis Subtrochanteric fracture after trauma

had been performed In three cases arthrodesis operations resulting in fibrous union had been carried out in two of these twice

TECHNIQUE OF OPERATION AND AFTERCARE

In the main the technique described by *Axer* (1961) was followed In eleven cases the head of the femur was completely dislocated at operation and all cartilage was removed from the joint surfaces In two cases the cartilage was partially resected without dislocation of the joint Good compression was achieved with the nail and its accessories in twelve patients Bone chips obtained at the operation and in some cases transplants from the iliac crest were placed around the compressed surfaces In one case the nail was wedged firmly in the ilium and compression could not be applied because it was considered to involve too great a risk of fracture of the osteoporotic greater trochanter

Figure 2 C The compression plate was replaced by a Thornton plate without a spring



The hip was as a rule fixed in a position of twenty five to thirty degrees of flexion slight outward rotation and in the frontal plane in the neutral position In four elderly patients who had a severe adduction contracture before operation the contracture was not completely corrected in order to avoid too great a change in pelvic tilt

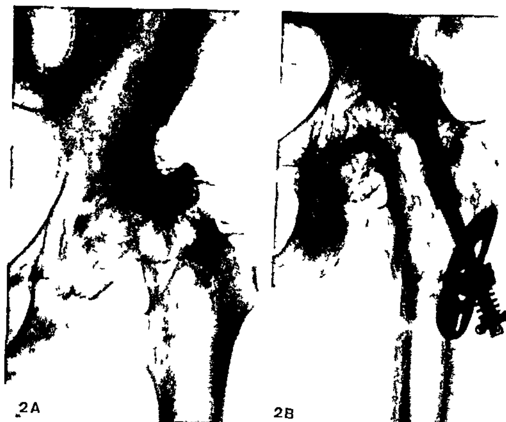


Figure 2. A. *Osteoarthritis of the left hip. Female, age 55 years.*
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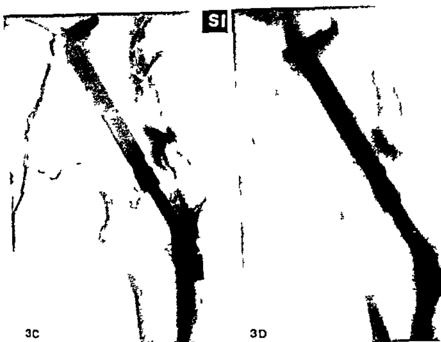


Figure 3 C Thirteen months after rearthrodesis by the method of Axer The nut the spring the compression plate and a part of the threaded bolt removed six months earlier
D Tomography confirmed bony union

Axer plate was replaced by a Thornton plate and at this operation is was found that the Axer plate had been pressed half a centimeter into the femur causing resorption of the lateral cortex The fracture healed in two months (Figure 2)

In one case the stop plate on the inner side of the ilium was found to have been loosened one month after the operation and the compression was lost A new stop plate was inserted and compression was restored In the same case the stop plate was later found to be buried in the osteoporotic ilium but the spring had maintained compression until fusion of the hip

In one case the position of the hip changed slightly towards more adduction during the first few days after operation However consolidation was obtained in a few months

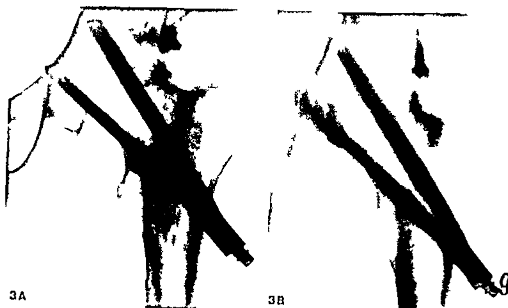


Figure 3. A. Condition seven months after arthrodesis a.m. Witt for sequels of traumatic dislocation. Male, age 33 years.
B. Tomography showed fibrous union as an explanation of pain.

The patients who were treated without plaster were encouraged to be out of bed on the first day after operation. Full weight bearing was allowed at a time varying between two to four months after the operation. One patient had a plaster spica for six weeks and another patient for three months.

The average stay in hospital after operation was thirty nine days. The preoperative range of motion of the knee could be maintained in all cases.

In ten cases in which the follow up time was more than six months fusion of the hip could be verified. In three cases the follow up time was 3–4 months.

COMPLICATIONS

One patient had postoperative thrombosis in the sound leg and another one a pulmonary embolus after change of the compression plate at a later stage. Both patients were cured by anticoagulant treatment.

Infection of the wounds did not occur in this series. In one case a subtrochanteric stress fracture occurred four months after the arthrodesis which had resulted in bony union. The fracture healed in two months, the patient using crutches during this time. Five months later the patient fell and sustained a fracture in the same site. The



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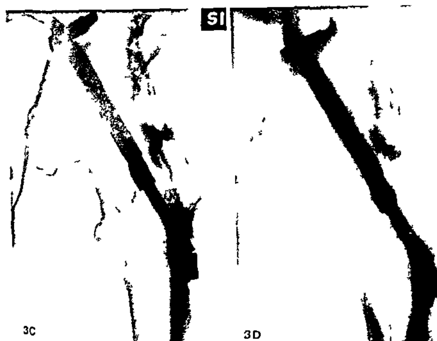


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DISCUSSION

When properly applied *Axer*s method for arthrodesis of the hip seems to us to allow early mobilization of the patient and full weight bearing of the limb two to three months after the operation The stay in hospital has been shorter than with any other method we have used

The femoral head should be dislocated at operation in order to allow the creation of compression between large raw surfaces of bone Good contact in the peripheral parts of these surfaces should be especially ensured The nut should not be drawn too tight on the spring because resorption of bone under the plates may follow The width of the compression plate makes it somewhat difficult to apply The lock of the stop plate could be more secure

Removal of the nut the spring the compression plate and a part of the threaded bolt (Figure 3c) is recommended in order to reduce the *risk of subtrochanteric fracture Figure 1 gives an example of the* successful use of the method in a case in which the femoral head was missing

SUMMARY

The compression method of *Axer* for arthrodesis of the hip joint was used in thirteen cases Eleven patients were allowed out of bed without a plaster spica on the first day after operation Full weight bearing was allowed two to four months later In ten cases follow up time was sufficiently long to allow the confirmation of bony fusion

RESUME

La méthode de compression d *Axer* pour l arthrodèse de l articulation de la hanche a ete utilisee dans 13 cas Il fut permis a 11 malades de sortir du lit sans bandage platre le lendemain de l operation La charge entiere du corps a été permise entre deux et quatre mois plus tard Dans 10 cas la periode d observation a été suffisamment longue pour que l on obtienne la confirmation de la soudure osseuse

ZUSAMMENFASSUNG

Die Methode von *Axer* fur Arthrodese des Huftgelenks wurde in dreizehn Fallen angewandt Elf von den Patienten waren aus dem Bett am ersten Tag nach der Operation Volle Belastung wurde von zwei bis vier Monate spater erlaubt In zehn Fallen war die Nachuntersuchungszeit lang genug um knocherne Heilung zu bestatigen

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PROCEEDINGS OF THE NORDISK ORTOPEDISK FORENINGS 33d ASSEMBLY IN GOTHENBURG JUNE 1966

The meeting of the Scandinavian Orthopaedic Association was held in Gothenburg under the Presidency of C Hirsch

METAL AS MATERIAL FOR OSTEOSYNTHESIS

SOME ASPECTS OF OSTEOSYNTHETIC MATERIALS AS A FOREIGN BODY

by *Hans Emnéus* (Lund Sweden)

Osteosynthesis presupposes a foreign body and this afternoon s topic concerns metallic osteosynthesis material

Osteosynthesis material is constructed according to the principles of carpentry In recent years biomechanical principles have to some extent been followed 50 years experience have taught us that the above principles are efficacious and that certain advantages over closed fracture treatment are to be gained The most essential feature for us has always been and is now a stable osteosynthesis Here however I shall be dealing in the first place with the biological activity of the foreign body not with the secondary effects of the osteosynthesis There will be a certain limiting approach therefore regarding what we on the whole consider to be the foreign body reaction It is therefore understandable that the mechanical or physical factor which is so fundamental both of the osteosynthesis and to the secondary effects of the osteosynthesis will temporarily move into the background in favour of the chemical properties of the foreign body and the appearance and behaviour of the surrounding tissue I will now divide the biological activity of the foreign body into two parts 1 The solubility of the foreign body in body fluids and 2 The effect of the dissolved substances on the tissues (Histology is involved in both 1 and 2) I shall first turn to the chemistry or electrochemistry of the foreign body All metals are to some extent dissolved by the body s electrolytes The electrolyte environment in the human body is composite but from the present point of view that of metallic foreign bodies all anions except the chloride ion can in fact be ignored Apart from the electrolytes pH and pO are also important From animal experiments it has been found that single isolated implants of high alloyed stainless steels cobalt chrome molybdenum alloys and titanium remain relatively the same in tissue In carefully regulated experimental conditions certain differences between these 3 metals and the tissue reaction can be observed In this experimental research no great differences could be determined in the histological picture I and my colleagues could see that different coloured pigments both phagocytized and non phagocytized were present around the different metals In the analysis in which

we used X ray pectrography we found iron around the steel implants cobalt around the vitallium implants and *titanium around the* titanium implants In America research was carried out using another techni que the tissue was ashed and analysed and the same result was found No special investigations have been made abroad experimentally in which consideration has been given to the properties of the foreign body treating it in ways which recall surgical procedure Admittedly *Laing* has *investigated screws treated by a specia*) screwdriver that is he has demonstrated the transfer of t ol metal to the screws *Stenram* and I found that there was an increase in tissue reacti n and pigmentation in the tissue when stainless steel wire was twi ted to cerclage comp ared with the insertion of an untreated wire Furthermore we discovered that identical steel inserts and two different types of cobalt alloy welded together produced a greater tissue reaction and pigmentation than if n isol ted piece of metal was placed in the tissue In parenthesis it may be said that isol te l vitallium implants thoroughly surface treated result in hardly any tissue *pigmentation*

As I stated just now a single piece of well polished stainless steel remains marked ly inactive and indissoluble in the tissues It is known that stainless steel however is passive thanks to a thin layer of chrome oxide This passive layer is perhaps 50 *or some 100* A (Angstom = 0 0000001 mm) thick If this layer is damaged corrosion will ari e In additi n in order to be completely passive the environment of the stainless steel surface must have a certain oxygen content If the surface of the stainless steel is damaged i e is hamme ed or in some way changed purely me *chanically the stainle s prop erties can be lost In cerclage for example the wire is twi ted A* pull is exerted on the wire which changes the wire s properties and can pro luce lo al surface damage where the chloride ions can attack and *corrosion arises (pitting* corrosion)

If two pie es of stainless steel are joined together *e g* screw and plate with a crevise the oxygen content in the crevise may become too low and the pa *ive layer cannot* maintain its passivity owing to lack of oxygen and then too there is a break *through by the chloride* ions r d the re ult is a orrosion(crevi e corrosion) Vital lium *probably has th same properties On the whole it can be said that there is a* pas ive l yer of itallium consi ting of chrome oxide It is thinner but vittalium ha *as it were* obu t r qualities If there should be a break through of the passive *layer* cob lt is n t t all so a tive as the iron beneath the passive *layer*

Fergus n and *Laing* have stated although I am not certain whether experimental evidence *f r this exi t* that vitall um is affected by crevise corro on but it ought to be ery rar

Finally there is titanium This element has quite specific properties Titanium is ext emely pa i e in a chlo de *environment and this is due to the fact the* titanium surf ce oxidi very rapidl and forms a thin oxide layer of titanium oxide The chl id ion t pH 7 can t *penetrate this oxide Chemically* titanium has probably *n ne of th* we kne *po e ed by steel* Surgical cold working ha as far is kn wn n gr t ignifican for its corrosion st bility

In clini l onditi n it is not to be expected that for example stainless steel will beh s (l ally a a ingle stainles steel *rod, thoroughly* surface treated beha es in n nim l bcdy W must expect the design of nail and plate and of screw and plate to pr du r sion in stainle s steel *in a chloride* environment *The surface* injuries which we produce with our this is the malformation of the screw head

effected when we turn the screw the twisting of the stainless steel wire when we carry out cerclage all this increases the biological activity of the stainless steel i e the solubility of the stainless steel in the body fluid increases It is probable that the same condition exists with vitallium but to a much lower degree

I shall leave the electrochemical process now and say a few words about the products which arise when the metals dissolve When stainless steel is dissolved by corrosion ionised iron ionised chrome ionised nickel and perhaps molybden are formed at the anode At the cathode hydrogen possibly is formed rapidly oxidised to H O When vitallium dissolves cobalt chrome and molybdenum are ionised When titanium is dissolved this cannot be precisely explained in electrochemical terms Truly ionised titanium scarcely occurs in the body

It is probable that it is not the quantity of heavy ions which is significant in itself but it is the toxicity of the ion One can expect that chrome and nickel are considerably more toxic than for example ionised iron We have evidence of this from experimental research by *Verne* and *Menegaux* & *Odiette* Undoubtedly chrome is very poisonous to the tissue and probably nickel also Iron is toxic but far less Theoretically then we may expect that a small quantity of chrome cobalt or nickel is itself equally as or more harmful than a large quantity of iron Vitallium consists of chrome and cobalt stainless steel of chrome nickel and iron Naturally I cannot prove it but it would not surprise me if it were to be found that a human being can tolerate iron in large quantity but very little chrome It is not known whether Cr^3 or Cr^5 is worse but this will emerge gradually

How then do the tissues look around the osteosynthesis material? In animal experiments the tissue reaction around implants of high quality stainless steel cobalt chrome alloys vitallium and titanium is very slight This applies both to the reaction of bone tissue and soft tissue Some fibrosis is always seen and often moderate amounts of monocytic elements isolated giant cells and isolated phagocytes filled with small quantities of phagocytised metal pigment Clinically quite a different picture is sometimes found Of course slight reaction is often seen exactly as in experimental research for example slight fibrosity moderate amount of monocytic elements isolated giant cells and almost always a small quantity of phagocytes filled with iron pigment

Sometimes however purulent dissolution and proliferation of leucocytes monocytes and phagocytes containing iron pigment are seen One often sees around stainless steel tissues of deep rust colour penetrated intensively by iron pigment and also other pigment great quantities of non phagocytised rust and considerable fibrosity An astonishing high amount of iron pigment is sometimes seen around vitallium

Occasionally even Turnbull negative pigment is seen i e pigment which is not iron but perhaps Cr Ni or Co By analogy *Stenram* and I have shown that Turnbull negative pigment with a probability bordering on certainty is precisely C Ni and Cr pigment What is important however is that these tissue changes around the foreign body with this abundance of pigment do not at all imply that discomfort of any kind has been clinically observed to result from the foreign body The patient perhaps may never have given a thought to the fact that he carries a nail or screw in his body There may never be any reaction at all from skin and muscles no radiological signs of loosening on the part of screw or plate Nevertheless considerable pigment may be present Naturally no purulent dissolution is then present

In other cases we have seen very severe reaction which expresses itself in the form

of an aseptic inflammation and almost osteomyelitic changes which then heal quickly as soon as the osteosynthesis material is removed What I wish to say is that in individual cases we have seen an inflammatory process surrounding osteo synthesis material inserted by us a process which does not show any bacterial infection and in which everything clinically indicates a chemical irritation In these cases we often discover an abundance of metal pigment in the tissue but we can expect to find equally as much metal pigment in the tissue of another patient who has not had the slightest purulent reaction

This means that we cannot in fact rely on a purely histological diagnosis to obtain indications concerning electrochemical irritation We know certainly that a dissolution of the foreign body has occurred in the tissue but we also seem to have determined that this dissolution of the foreign body does not affect different individuals in the same way Certain individuals do not tolerate a biologically active foreign body in their organism Here the question occurs whether the toxi ity previously mentioned is sign ficant Some humans could well be sensitive to for example chrome and thus react more intensely even to slight corrosion of the inserted for eig ı b dy

It was always my idea and dream that the histological picture could be evaluated by some analytical meth d and that one could say that there is chemical irritation here I advanced along various paths and during this search I merely found that there was always a defensible proportion of the heavy elements in the tissue The elements found in the foreign body were present in the surrounding tissues It is thus shown that chemical solution will always occur In clinical experiments I also foun l c balt and chrome around vitallium applications Sometimes I found large quantities of titanium around titanium apr l cations but no answer was produced to the question whether there was any chem cal irritation in the individual case

The whole material may l e summarised as follows cons derable metal may be present in the ti sue l ut nc chemical irritation can be demonstrated clin cally If however there is an b ious su picion clin cally of chemical ir itation then an abun lance of p hag cytic an l non phagoc tic metal pigment ought to be present e t ue pigm nt A c n i tent featu e of all the experimental re earch and of the single l e mpar on i that a s l tary applicat on of a met l whichever one of the three pr du es quite light pigm ntat on f ti sue nd very rarely any chemical irritation C mb ned o teosynthe is materi l onsi t ng of a number of tructures pro l ic n tant t ue pigmentation and ne uspects chemical irritation con si lerab ly m e ften Th re i no d ubt th t stainle s steel is m re irritating chemi all th n itallium l ut t m t l be reali ed that stainle s steel can rust consi lerably with ut affe ting th t ssue Vit llium rusts rarely l ut we must neve theless be p p r l for hemi l i r tati n f m time to time Titanium seems to provoke very slight ti u r acti n W th tit ni m applications an al und nt quantity of black pigm nt i metim f und in the tissue but *the body h* s quite a good tolerance les l f thi pigm nt W th n f r ign bcdy cap ules be a ound the titanium ap pl ti n and the l ve i po ibly due to the *fact that tit* nium does not occur in i n f m i th ti e l ut i xi li ed r pidly and th t titanium oxide has a good t le anc l l

I can gi no th r umm ry of the pre ent day *situation* th n that vitallium is xcell nt a o t o nthe i mat rial St inless steel ha its limitations and therefore when Moore pr th re in l e l then on ought perhaps to reject steel Titanium

probably is on an *equal par with vitallium* in Moore prostheses At this point I will only say that titanium holds its place by the side of steel Dr *Gudmundsson* is shortly to give an account of our clinical research into titanium

DISCUSSION

E Sandaa (Sandvilen Norway)

A Lambott s plate with screws was *removed 23 years after application for femoral* fracture in a girl of 17

The plate was found reduced to a thickness of ½ mm the screws were also grossly *corroded The foreign bodies* were surrounded by a thin walled sacculus containing a homogeneous mass consisting *inter alia* of a rather high concentration of the metals constituting the plate and screws and in the same proportions (Plate and screws Major element Fe minor elements (0 5 to 0 02 pct) Mn Si Cu Ag Ni Co) The mass also contained P Ca and Mg proportional to bone the percentage of P higher of Ca smaller than that of Fe There was very marked pitting destruction of bone under and around the plate the bone being partly necrotic It was found that approximately half the weight of the plate had been resorbed during the years one fourth retained *in the sacculus*

The local toxic effect and possible toxicity of resorbed metals are briefly discussed —The alloy used in this case now is obsolete but even osteosynthesis material *of modern allows should* be removed from young and middle aged persons

MICROANGIOGRAFISKA OCH HISTOLOGISKA OBSERVATIONER VID KOMPRESSIONSOSTEOSYNTHES

by *S Olerud* & *C Danckwardt Lilliestrom* (Uppsala Sweden)

FINAL REPORT ON THE CLINICAL TESTING OF TITANIUM

by *Hans Emneus* & *Gudmundur Gudmundsson* (Lund Sweden)

As stated in our preliminary review 1964 Titanium seems equally suitable for use *for hip prosthesis af Vitallium* and this impression has been confirmed *by our* extended survey Since 1961 150 Moore plastics have been performed with Titanium prosthesis strictly alternating with Vitallium

During the period January 1962 until October 1964 a series of 88 McMurray osteotomies were carried out by the Tupman method

Table 1

	Arthrosis def	Necrosis cap fem	Pseudarthrosis colli
Steel	46	8	54
Titanium	30	4	34
Total	76	12	88

For most purposes Titanium seems quite comparable to other osteosynthesis materials in current use After one has become accustomed to its special qualities one can work very well with it In comparison with steel its mechanical strength under exacting conditions appears to be somewhat inferior

Since this series was started 11 of the Tupman plates have broken

Table 2

	Inserted	Broken	
Steel	54	5 (6)	9 3 % (11 1 %)
Titanium	34	6	17 6 %
Total	88	11	12 5 %

The tissue is sometimes blackened by the Titanium applications It is extremely interesting that Titanium osteosynthesis material adheres to the tissue and that in spite of abundant manifestation in both phagocytic and non phagocytic form it does not cause any tissue react on

INTRAMFDULLARY TRANSFIXION AN EXPFRIMENTAL OSTEOSYNTHESIS

by *Borge R Hansen* (Copenhagen Denmark)

Ffficient stabilization nd adaption are fundamental in the operative treatment of fractures These f ctors were basic to the design and construction of an experimental oste s nthe i the intramedullary transfixion

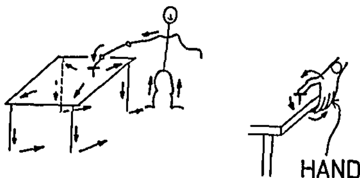
Two sta nles steel wires bent and threaded in extremities were placed crosswise over a t an erse osteotomy on the femur and tightened with nuts This resulted in a ompre sive force o er the osteotomy

In a eries of pilot experiments on d gs operati e techniques were elaborated Fxt rn l immobilization was n t effecti e so the transfixion was supplemented with a plate fixed with two screws In thi way bone healing progressed without external or intram dullary callu f rm tion

AN FNGINFFR S VIEW OF ORTHOPAEDIC NAILS AND SCREWS

by *H Jak bss n* (C teborg Swe len)

Th ight f n orth pa di u geon inse ting a nail or a screw into an intact or b k n bone i an eye-open r for a me hanical engineer He is conf onted with p l lem he had ne er thought of bef re It is obvious that such foreign bodies must be m de of suitabl m teri l i e it must t lerate the environments in the body it mu t be t g enough t t nd the stre s and strain to which it is subjected and it mu t hav ufficient fatigue strength At the same time it should have no injurious effect on th body ti ues but rather p om te he ling and regeneration As fa as the ctu l m terial is con erned much progress has been made and further research is in progr Thi point will therefore not be dwelt on further here



LONG DISTANCE SHORT DISTANCE

Figure 1 Force flow Thumb tack in a table

I admire the skill with which the surgeons gain access to different parts of the body and fasten appliances there But when it comes to the designing of the appliance I feel that a mechanical engineer might be a valuable link between the orthopaedist and the manufacturer of the parts of the metal appliances

What I intend to elucidate here is the properties of a screw and of a nail In other words what can a nail or screw do? But this is not enough The question must be expanded to read What can a nailed or screwed joint do for it is such appliances that we want to create I do not know whether this problem has received any attention in the orthopaedic literature At any rate I have not seen any articles on it

The purpose of a joint is to fix displaced or movable parts This means that the splint must be strong enough to withstand forces tending to break or bend it The forces must be taken up by the mechanical construction

Below are a few recommendations I give to my students at Chalmers Tekniska Hogskola

Rule I

Visualise all the forces as a stream or flow of force It flows something like an electric current and makes a circuit (Fig 1)

It is as a rule advisable to choose a short force flow circuit

The circuit should be determined and designed by a mechanical engineer who should also see that the various parts can stand the forces they are to be exposed to The flow of the force should not be offered various paths but should be confined to a single well defined one

Rule II

In the same way all twisting moments together form a moment flow which also forms a closed circuit (Fig 2)

The circuit should be short and the various parts should be strong enough to tolerate the flow

When designing a nailed or screwed joint the first question to be answered is What are the directions the magnitude and the sequence of the forces to which the appliance will be subjected

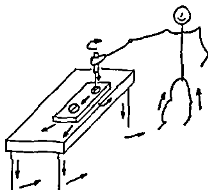


Figure 2 Torque flow Tightening of screw

If numerical values are not available for such forces they should be estimated and overestimated rather than underestimated

Not until this has been done is there any sense in discussing the actual design of the appliance

NAILS

Nail Joints

A joint usually has several cooperating nails Let us first consider a joint with two nails (Figure 3) The nails may be round or angular

Figure 3a illustrates a joint made of perspex nailed tight to a wooden support. The joint is designed to take up forces P P_y and a moment M all of which tend to shear the nails Elastic deformation bends the nails a little A force P which is directed downwards does not affect the nails If P_z is directed upwards it tends to extract the nails The result depends entirely on the elastic pressure between the nail and the piece of wood and its ability to retain the nail by friction

No nail should be exposed to such forces unless it is securely fastened in the lower part B x nailer hammer the nail right through the wood and then bend its tip One can also in s me w y or another produce a sort of barb to prevent withdrawal of the nail from the lo er p rt

Figure 3b sh ws a spaced j int with (or in extreme cases without) springs in the spa e b tween the p rts F en 3a should be drawn in this way because there is al way a tain am unt of ɛl y or la ticity in the pieces assembled The more ob vi us el ticity in 3l can ousually well take up P_x P_y and M_z But the nai s are d f rm l mor in ben ling and the parts therefore move appreciably in relation to one another

Interesti g i the l wnwa dly directe l P Using simple alues let us suppose that aft r n iling each ɪ ing is compres ed with a force of 10 kp (1 kp = 2 2 lbs) then an extra ting f rce of 0 kp will be cting on e ch nail When P increases from 0 to 40 kp th n il will be compl tely unloaded an l the springs will be compressed with 4 10kp l 1 To pr the upper pl te down over a nail would require say

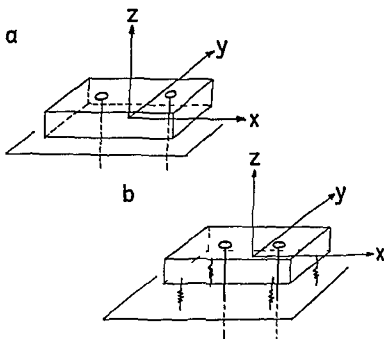


Figure 3 Nailing a Tight b Untight

50 lp to overcome the friction While P_z increases from 40 to 140 it will have no effect on the springs but each nail will increase its load from 0 to 50 If P_z is increased further the forces of the nails persist and the springs take up 0 2 (P_z 100)

When P_z is afterwards removed the upper plate is lifted and then friction exerts a pull of 50 lp on every nail which tries to extract the nail from the lower part of the construction

From a technical point of view a joint with such play is unacceptable I would forbid P_z Mechanical play wears out a joint and what do the springs think of massage They may be healing bone surfaces

Single Nail

It is very difficult for a single nail to transfer torque about its own axis Otherwise it acts as a nailed joint

To cope with this torque the nails are made angular or flanged *This prevents* rotation but since the lever is extremely short the moments acting can produce enormous forces in the material around the nail

I must confess that I cannot understand why a three flanged nail should be better than a one or two flanged one

Insertion of Nails

As a rule *the nail itself produces the hole it is fastened in Insertion of nails onto* bone must be done with extreme care to prevent the surrounding bone from cracking or splitting Therefore the holes to receive the nails are sometimes prepared in as gentle a way as possible *e g* boring and broaching But the hole most always be widened by the actual nail if the latter is to be retained by elastic friction

I feel it would be a great advantage if the nail could be held in position by a barb instead of by friction

When in the course of nailing the tip of the nail reaches the lower part it tends to separate the two parts from one another unless there is a very good support for the lower part

Personally I think nailing is a very crude operative procedure I do not know how the forces inside the nail behave (during insertion of the nail) I do of course appreciate the precision of the direction of the nail made possible by pre insertion of a small cylindrical guide in the bone

Removal of Nailed Joint

When designing a nailed joint consideration should also be given to the possibility of its removal should it prove desirable I presume that orthopaedic nails must be designed in such a way that they can be readily extracted since the healing process or disturbances during this process may make it necessary to remove or replace the joint or replace it by a more suitable one

Screws

The principal difference between a nail and a screw is that the screw can withstand traction forces without being dependent on the aforementioned friction between its own surface and that of the surround ng material The screw is instead d pendent on the shear strength of its own threads and that of the recipient material Metal is as a rule strong enough but in bone the threading cut by the s rews may not be

For a screw or nut not to become loose there must be sufficient friction between its threading nd the recipient material unless of course some special locking device is used

Screwed joints can take up the same type of loads as nailed joints If angular in er ss ection and fa tened by n exterior nut a single screw can take up a torque about its xi The screw need not rotate in its hole due to this nut

Mount ng of a Screw

A screw must first be sc ewed in to get a certain traction preload This preload gives prima ly the fri tio locking action just mentioned Due to this preload the two j inte l pieces do n t part lastically when the working load acts on the joint

Figure 4 hows a metal splint with 2 screws fastened to a base plate When the driving for e P_{DRIVE} is not cting the screw is drawn by the force P_{FRONT} Then the scr w is ela tically defo med as shown in the diagram and compresses the upp rt el tic l y When P_{DRIVE} i exerting its action the screw lies against the supp rt with a tightening force of P_{TIGHT}

If the screws ar n t d wn tight enough there will be a certain amount of play in the j int which i rarely ceptable

When the screw i screwed tight the m ment of the screw spanner is transmitted d wn to the h nk of the screw and to the support under the head of the screw or the nut It i then transmitted further as a moment flow back to the hand tightening th screw (Fig 5)

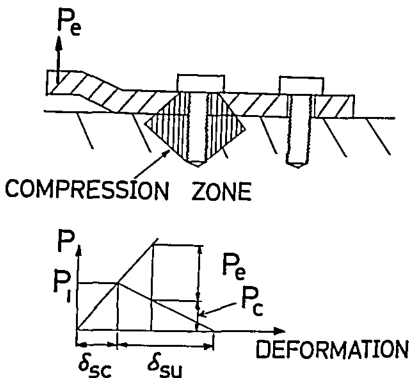


Figure 4 Tightening of screw

P_I = *Initial screw load*
P_e = *External load*
P_c = *Contact load*
δ_{sc} = *Screw elongation*
δ_{su} = *Support compression*

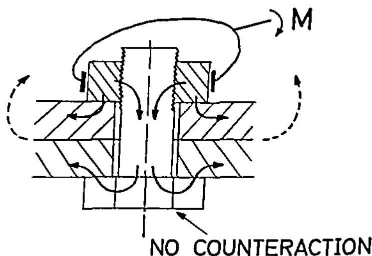


Figure 5 Flow of tightening torque

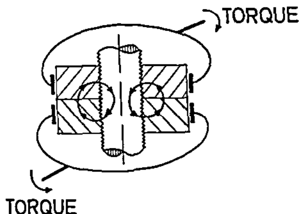


Figure 6 Lock nut Only internal force flow

L ckı g of the Screw

In those cases where screws or nuts are liable to become loose I would recommend attempts to find a suitable construction Generally speaking I would recommend two nuts They should be screwed tight against one another so that the friction thereby produced in the threads will hold them firmly They can be drawn very tight because there is no body tissue in between them (Fig 6)

Effe t of Bone Tissue

Both nails and screws are dependent on the ability of the bone to retain its elasti city for the nail must fit tight and the screw must hold its grip The construction sh uld theref re be such that the bone will keep its rheological properties as long as the splint i to be w rn I feel that experiments of the *Sedlin s* type might be useful in as essing what the bone can tolerate

The Three Flanged Nail for the Femoral Neck

Thi n il s metimes loo en nd slips Thi is what I think h ppens

Wh n the n il i l ing inserte l the two f agments are n t firmly held together (Fig 7) It i r l al ly hel l by fricti n at both en ls The site of the fracture may be r gar le l a an l tic interm li t l y When the patient is w lking a large pul sating xi l f e l t on the left h lf of th head

Thi f c i tak n i p p tl y () I b the friction g p at the head of the scr w nd the r t (1 0) P is tran mitted through the resilient fracture zone This a ne d termine tl omp sion distance which is al the d stance the nail head lip ut f the b ne Thi l pping of the n il hel l l y friction results in development f h t Wh t h ppens hen P di ı pear ? That depends on the value of Q

a) Q<50 p r nt 30 per cent The pring carries 70 per cent of P_x when P_x is in cti n A l li ıı the spring l ad decr e ls pre ented by the friction force in tl right fragment This fricti n force has now the opposite directi n The spring l d will rem in t 0 30 P wl ich is l lanced by the friction of the right fragment. It hou ld be l erved that the s me f rce tries to draw the left end of the nail from

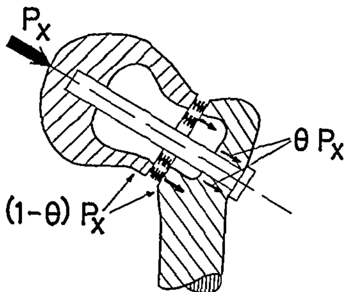


Figure 7 Collum nail

its hole If the friction grip of the left end of the nail is smaller than that of the right end the nail slips out of the left hole When $P_x = 100$ per cent is again applied the spring resists with 30 per cent while the friction in the right fragment changes direction *While the spring is compressed from 30 per cent to 70 per cent* the nail slips to the right again etc In fortunate cases the nail may slip back again into the left hole

If the friction grips are not equal when the nail is slipping to the left and to the right I can imagine that the nail may work its way out

b) $\theta > 50$ per cent say 60 per cent The spring carries only 40 per cent of P_x and cannot reverse the friction to slipping in the other direction The right friction is reversed without slipping of the nail to a value of 40 per cent This force will then draw out the left end of the nail If the two ends have identical frictional properties there will be no risk of nail slip

In the light of the simple considerations above I would recommend that the head of the nail also be a barbed Provided the healing of the fracture is not promoted by kneading and that the fractured region does not tend to contract

The plate that is screwed to the femur to hold the nail in position does not appear to be so very good It places large demands on the screws Can the screws always fill these requirements? Or can the force seek one way or the other by itself A properly mounted splint eliminates massage of the fracture area and prevents shortening of *the fractured region during healing*

Concluding Remarks

Attempts *should be made to find out the most suitable designs from a* purely mechanical point of view of screwed and nailed appliances for various orthopaedic purposes In cooperation with orthopaedists these designs should then be modified to satisfy the medical requirements I think that close cooperation between mechanical engineers and orthopaedists in this respect should prove fruitful

BONE AS MATERIAL FOR OSTEOSYNTHESIS

CORTICAL BONE AS MATERIAL FOR OSTEOSYNTHESIS

by *I Alvik* (Oslo Norway)

INVESTIGATIONS ON THE OSTEOGENESIS IN AUTOTRANSPLANTS OF BONE

by *H Bohr H O Ravn & H Werner* (Copenhagen Denmark)

Recently it has been shown by *Langenskiold* and *Puranen* (Scandinavian Orthopaedic Meeting in Helsinki 1964) that fresh autografts of bone have a more intense uptake of Tetracycline than autografts which have been kept for one hour in air or three hours in saline indicating a greater osteogenic power in fresh autografts

In order to study this phenomenon more closely the bone formation in autografts transplanted under various conditions was observed through repeated labelling with Tetracycline A graft was taken by hand drilling from both iliac bones of rabbits Some of the grafts were immediately replaced while others were kept for one hour in saline or exposed for one hour in air before replacement 5 days after the transplantation the animals had an injection of Terramycine (Oxytetracycline) and 5 days later an injection of Ledermycine (Demethylchlortetracycline) was given The animals were killed 15 days after the transplantation and decalcified specimens about 70 µ thick were prepared from the transplantation sites Through microscopy in ultraviolet light it was possible to distinguish between the bone formation at the time of labelling due to different fluorescent colours of the Tetracycline compounds used Out of a total number of 70 transplantations 15 were made with fresh autografts, 15 with autografts kept in saline 16 with autografts exposed to air and 10 with Kieler grafts (processed calf bone) to the iliac bone as a control Further 6 fresh autografts and 9 Kieler" grafts were transplanted to soft tissue subfascially on the back of the animals From the table it is seen that in about half of the fresh autografts and of the autografts kept in saline bone formation could be demonstrated between labelling on the 5th and 10th day after transplantation while in autografts exposed to air only 14 per cent of the sections showed distinct double labelling 10 days after transplantation the bone formation was also more pronounced in the fresh

Summary of Postoperative Bone Formation Percentage of Sections

Graft	Transplantation Method	Transplantation Site	Bone formation on transplants days after operation 5	10	15	Total callus formation
Auto	Fresh	Bone	54	80	89	95
Auto	Saline	Bone	42	72	9	100
Auto	Air	Bone	14	62	83	95
Kieler"		Bone	0	5	70	100
Auto	Fresh	Soft tissue	0	91	91	91
Kieler		Soft tissue	0	0	0	0

autografts and in those kept in saline than in the *autografts exposed to air* 15 days after the transplantation however the bone formation was about equal in the different groups of transplants to bone including Kieler grafts In the fresh autografts transplanted to soft tissue bone formation was usually observed from the 10th day but no bone formation could be demonstrated in Kieler bone transplanted to soft tissue In a supplementary experiment an injection of Ledermycin was given to 4 animals one day before transplantation of fresh autografts to the iliac bones An injection of Terramycin was given 5 days later and the animals were killed 10 days after the transplantation From this experiment it was shown that in the majority of fresh autografts new bone is already *produced from* the first day after transplantation

THE FIRST STAGES OF ASSIMILATION OF A BONE ISOGRAFT STUDIED WITH 3H-THYMIDINE

by *J Delu A Bertelsen & Bro Rasmussen* (Copenhagen Denmark)

Since the work of *Reichard & Friedlin* demonstrating the utilisation of desoxyribosides in the biological synthesis of polynucleotides thymidine in its tritiated form has largely been used for localisation of cell nuclei in their DNA synthesis phase

Regions of proliferative activity can be detected in many tissues and the differentiation of cells from one stage *to another can be investigated*

Studies of this kind have been carried out on normal growing bone in an attempt to determine which cells can be considered to be osteogenic or precursors of the osteoblasts how rapidly they divide and differentiate into blasts and cytes

Although sex chromatic studies had already demonstrated that a certain amount of the bone newly laid down after transplantation was due to the activity of graft cells *Ray & Sabet* were the the first to use 3H-Thymidine in the study of bone graft They were able to demonstrate that labelled isograft cells could produce new bone for they showed labelled osteocytes 2 weeks after transplantation in unlabelled animals Unfortunately they reported some osteocytes labelled in the graft at the time of transplantation

It is our purpose to study the very first stages of assimilation of a labelled isograft in an unlabelled animal

6 week old white mice were injected with 1 μc/gr of their body weight 4 times at intervals of 6 hours and were *killed* 2 hours after the *final injection* The upper tibial metaphysis next to the growth plate was excised and put immediately into normal saline and cut into small pieces of 1 to 2 mm^3 which were inserted in the anterior chamber of the left eye of 40 6 week old mice highly inbred with the donors as an isogenous cancellous graft

The same experiment was carried out with albino wistar rats The hosts were *killed* at the following intervals after transplantation 1 2 3 3½ days then every 6th hour until 5½ days then 6 7 9 11 and 17 days The vessels were perfused with 1 1 2 per cent blue berlin + micropaque mixture The specimens were then fixed in *neutral* formalin decalcified in 18 5 per cent Versen embedded in paraffin and cut into 7 μ sections The sections were put on gelatine glasses and after removal of the paraffin were dipped in 1 2 diluted photographic emulsion Ilford K 2 allowed to

dry and then stored for 6 weeks at a temperature of 4 The sections were then devel ped and stained with haemotoxylin eosin and mounted

Results

At the time of transplantation 32 per cent of the osteogenic cells and 17 per cent of the osteoblast like cells were labelled (in mouse) There was no labelling of the osteocytes By vessel injection it could be seen that some of the labelled cells were includ d in the vessel wall

It was not possible to obtain injection of the graft vessels before the 4th day Most of the transplants were injected by the 5th day Before vascularisation was est blished many cells died but labelled cells appeared to have more resistance as the percentage of labelled cells showed an increase inside the graft Outside the graft cellul r connection was established between the outgrowth of graft cells and the granulation tissues from the host Labelled fibroblast like cells were seen outside the graft

As soon as the vascularisation was reestablished the number of cells increased considerably inside the transplant By the 5th day 6? per cent of the cells were labelled but the number of grains per cell was markedly decreased In the injected specimens some of the labelled cells appeared to be included in vessel walls

Pictures of resorption and osteogenesis were seen from the 5th day onward and most of the grafts showed them by the 6th day Cells were labelled in relation to these phenomena N osteoclast was seen before the 6th day and these may have contained labelled nuclei side by side with unlabelled nuclei No labelled osteocyte was seen before the 7th day

Conclusions

These experiments give further support to the theory that living cells from the transplant actively contribute to

fib us fixation of the graft to the host bed
vascularisation of the graft
bone re orption and new bone formation

TREATMENT OF PSEUDARTHROSIS WITH DEPROTEINISED HETEROGENOUS BONE

by *K. B. Isgaard Sørensen* (Copenhagen Denm rk)

Pseudarthrosis on the diaphysis of both ulnae was produced in 23 rabbits by resection of the bone and interposition fo 6 week of inert materi l Tran plantations with fresh autogenous bone and with deproteinised heter gen u bone (Kieler" bone) were made as onlay grafts and a comparati e tu ly of the healing was per formed during th interval from 2 weeks to 4 month Tw days before the animals were killed they r ei e l an injection of Tetracycline and of Ca[45] Through histolo gic l stu l s an l in estigations on the undecalcified pe imens g ound to 100 µ thi k it was h wn th t the healing effect wa d c isely lower with "Kieler" bone than with aut graft New bone f rmati n c rresp n ling to the pseudarthro i was se n in all the autogr fts but nly in 20 per cent of the grafts with Kieler" bon No immun l gic l re ction against the "Kieler tran plant wa observed Hi t l g lly

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TRFATMENT OF PSEUDARTHROSIS WITH DEPROTFINISED HETEROGENOUS BONE

by *K B adsgaar l S rens n* (Copenhagen Denmark)

Ps ud rth osis on the d phy sis of both uln e was produced in ?3 ral bits by resection f the bone nd nte position for 6 weeks of inert material Transplanta ti ns w th fr h autog nous bon and w th deproteinised heterogenous bone (kieler bone) were ma le onl y grafts and a c mparative study c f the healing was per formed during the interval from 2 weeks to 4 *months Two days before the animals* were killed th y recei e l an inject n f Tetracycl ne ar d of Ca^{45} Through histolo gical stud es and n st g ti n on *the undecal ified* pecimens g ound to 100 μ thickness it w s h wn that the heal ng effect was decisively lower with "kieler" bone th n with aut g ft \e l one formation c rresp nding t the pseudartl ros s w s seen n ll th aut graft l ut only in 20 per cent of the grafts with kieler" bone \o imm nolog l reaction ag *inst the* Kieler transplants was observed hist logi ally

It was concluded that deproteinised heterogenous bone is not suitable for the treatment of psuedarthrosis

TREATMENT OF PSEUDARTHROSIS WITH DEPROTEINISED HETEROGENOUS BONE AN EXPERIMENTAL STUDY
by *R Movin* (Copenhagen Denmark)

BONE TRANSPLANTATION WITH THIN CORTICAL GRAFT FROM TIBIA
by *F Madsen* (Soro Denmark)

Pseudarthrosis and delayed fracture union were treated by transplantation of a 3–4 mm *thick* cortical graft from the upper end of the tibia fixed as an onlay graft by 4 vitallium screws Resection of the bone ends was carried out only when the fracture position was unacceptable Bone chips from the local callus were placed around and superficial to the fracture site

51 operations are reported 49 of these ununited fractures healed after the operation One of the two failures was caused by bone infection

Healing time	1½ – 2 months	24 cases
	2 – 3 months	13 cases
	3 – 4 months	6 cases
	4 – 6 months	4 cases
	6 – 8 months	2 cases

DISCUSSION

H Heikel (Borgå Finland)

OSTEOTOMIES

THE INFLUENCE OF COMPRESSION ON THE REPAIR OF EXPERIMENTAL OSTEOTOMIES OF THE FEMORAL NECK
by *P Rokkanen* & *P Slätis* (Helsinki Finland)

The beneficial effect of compression on the healing of fractures of spongious bone is well established Fractures of the femoral neck however constitute a special problem since the femoral head is often thus deprived of its blood supply and as a result becomes more or less avascular In order to investigate the repair process of experimental osteotomies of the femoral neck with special reference to the use of compression the following experiments were performed

On 42 full grown rabbits the left hip was opened the ligamentum teres severed and the femoral neck osteotomized with a circular saw The fragments were held together with a bolt introduced through the center of the femoral head and tightly fixed with a nut on the lateral side of the femoral shaft In 24 animals a spring load was added to the device exerting a continuous 30 g/mm compression on the fractured *bone ends* The healing of the fracture and the subsequent changes in the femoral head were investigated radiographically histologically and by a tetracycline labelling technique 1 3 6 and 12 weeks after the operation

In the groups of animals in which continuous compression on the fractured bone ends was applied more rapid fracture repair was observed The avascular necrosis of the femoral head following luxation and osteotomy could not however be lessened and the trabecular breakdown and flattening of the femoral head was pro found in these experimental groups

It is concluded that continuous compression on an avascular spongious fracture fragment should be used with caution since the necrotic bone cannot withstand continuous pressure when reorganized by invading regenerative tissue

OSTEOARTHRITIS OF THE HIP JOINT AND INTERTROCHANTERIC OSTEOTOMY

by *K Kallio & O Klossner* (Helsingfors Finland)

Altogether 152 osteotomies of the MacMurray type for osteoarthritis of the hip joint were pe formed at the Hels nki Universit Orthopaedic Clinic during the years 19 6–1963 The follow up exam nation extended to 136 ca es 57 males and 79 fe males The oste arthritis was regarde l as primary in 91 cases and as secondary in 45 cases Internal fixation of some kind was always used the first 8 cases had a supple mentary hip plaster spica but all the other 128 cases were treated in skeletal traction usually fo 3 to 6 weeks The observation period was above two years in 94 per cent of the cas s and 1 2 years in 6 per cent of the cases only The patients own assess ment of the result is seen in Table 1 How the hip pain was relieved by the osteotomy is seen in T ble 2

Table 1 The patients asse sment of the result

	I im ry osteoarthriti	Secondary osteoarthritis	Total no of ca es	Percentage
Definitely better	68 ca s	31 cases	99 c ses	73
Somewhat b tter	18 c ses	10 cases	28 cases	20
No change or worse	5 ca es	4 c ses	9 cases	7
Total	91 a es	45 cases	136 cases	100

These patient came f r surg c l treatment at a rather late stage of the disease The p eoperative range of the extensio flexion movement (measured without an aesth si) wa bel w 60 degrees in 47 per cent f the cases and in 35 per cent of the cases both hip were ffe ted at least to s m extent. Neverth less the results seem to be surprisingly good The preoperative p n had disappe red or was relieved in 90 pe c nt of the ca e Th ults seem to have *been* la ting as during the obser vation p od pain returned in only 10 pe cent although fixation of the fragments had n t b en rigid

Th re ult w l lt r f) the operation was performed at a comparatively early stage of the disea e when the r nge of flexion movement was more than 60 degrees b) the m d l di pla em nt of the d stal fragment was one half the diameter of the bone or m re in primary o teoarthritis *c)* the fragments were tilted to a varus or valgus po ition instead of being in the same direction as before the osteotomy

Table 2 Effect of osteotomy on hip pain

	Primary osteoarthritis	Secondary osteoarthritis	Total no of cases	Percentage
No pain during the observation cases	32 cases	18 cases	50 cases	37
No pain at first but pain returned to some extent	11 cases	2 cases	13 cases	10
Pain was relieved	41 cases	19 cases	60 cases	43
The operation had no effect on pain	7 cases	6 cases	13 cases	10
Total	91 cases	45 cases	136 cases	100

In concluding we would say that the patients seem to be surprisingly satisfied with the results of an intertrochanteric osteotomy for osteoarthritis of the hip either primary or secondary even when the operation was performed at a rather late stage of the disease Nevertheless some patients spontaneously regretted that they had not had the operation earlier If a patient has disturbing pain and good mobility in the hips an intertrochanteric osteotomy offers a reliable solution to the problem Theoretically an early osteotomy seems to be advisable But it may be asked are the patients anxious to have the operation if they have no noteworthy pain?

FIXATION WITH BOSWORTH'S SPLINT BY INTERTROCHANTERIC OSTEOTOMY

by *Ulf Lucht* (Odense Denmark)

In the Orthopaedic Clinic of Odense Bosworth's splint was used for fixation in 64 intertrochanteric osteotomies during the period 1957–1964 57 osteotomies were performed for the treatment of osteoarthrosis coxae and 7 osteotomies for the correction of wrong position in the hip Bosworth's splint which is made of vitallium is a straight blade plate It is easy to position and does not require an X ray control on the operating table The splint fixes rotation flexion and abduction and supplementary external fixation with a plaster of Paris is normally not necessary 43 osteotomies healed within 3 months and 13 healed within 6 months In 3 cases there was delayed healing with a healing time up till 1 year and in 5 cases non union occurred The cause of delayed healing was a bad contact on the osteotomy site In 2 cases the non union was due to bad contact combined with great displacement in 1 case a wrong placing of the osteotomy line in 1 case a wrong placing of the splint and in the last case non union occurred after primary healing as the patient fractured the collum femoris 1 year after the osteotomy On the basis of the examination of the literature and my own experiences the following factors must be observed if one is to avoid complication in the shape of delayed healing and non union when using this form for internal fixation

1) Correct intertrochanteric placing of the osteotomy line
2) Correct placing of the splint whose point must penetrate the cortex over trochanter
3) Good contact between the bones before fixation of the splint on corpus femoris one must ensure that trochanter minor does not hit the caput femoris
4) No charging before X ray healing

THE RESULTS OF OSTEOTOMY AND OSTEOSYNTHESIS IN COXARTHROSIS

by Svend Rosendahl & Jørgen Ernst (Copenhagen Denmark)

Sixty patients with osteoarthritis of the hip were followed up 2 5 years after upper femoral osteotomy with osteosynthesis Two thirds were females in the 6th and 7th decade and the original diagnosis was primary osteoarthritis (21) incongruent hip (6) and othe conditions (18) A good or fair result was obtained in 39 cases un changed or bad in 21 cases (40 per cent)

The placement of pin or plate in the trochanter makes no influence to the result of the treatment and postoperative fixation with plaster cast improves neither the healing nor the final result There is no relation between the re ults and the different s rt of plate and pins used f r fixation of the osteotomies

In 21 val us osteotomies there were 7 pseudarthroses

In 29 varus osteotomies there were 8 pseudarthroses

In 15 osteotomies with simple displacement there was pseudarthroses in 2 cases

In the 17 pseudarthrotic cases the osteotomies were placed below the lesser tro chanter in 10 and in one case there w s a psoastenotomy The intertrochanteric placement of the oste tomy is important in obtaining better fixation from the psoas tendon and so psoastenotomy should be avoided

RESULTS OF INTERTROCHANTERIC VALGUS OSTEOTOMIES IN HIP ARTHROSIS

by Bengt Tillberg (Harnosand Sweden)

During the years 1956–1960 97 intertrochanteric osteotomies were performed at the Institute for Cripples Harnosand two of these were b l teral and carried out acco d ing to the technique described b low The present results are based on personal f ll w up of all cases

Indications

Prim ry arthro i w th ach ng while re ting and pa n on weight bearing together with flexi n of at lea t 60 degrees and addu tion ability are essential indications Age at operati n was in 13 cases 41 50 year in 51 cases 51–60 years and in 31 cases 61 70 ye s The e we e 50 men and 47 women and a m nimal observation period of 5 years and an aver ge of 6 4 years

Operative Procedure

Int rtrochanteric wedge oste t my w th lateral b se according to the calculated d gree of lg s in it turn d pending on the preope ative adduction ability Cor recti n of malpositi ns medial di placement of the femoral fragment and fixation with nail pl te d modum McKee Nissen Physiotherapy after 3 weeks and we ght bea ing after 6 week

Postoperative Complications

There was 10 per cent delayed skin healing without positive bacteriological culture 10 per cent thrombosis and 6 per cent pseudarthrosis which were reoperated on and healed

Subjectively 70 per cent completely satisfied 18 per cent satisfied apart from stiffness and 12 per cent dissatisfied owing to unchanged trouble and 7 of these were reoperated on according to another method—hip plasty or arthrodesis

16 per cent completely free from pain 42 per cent insignificant pain of short duration 9 per cent had solely weight bearing pain 3 per cent had aching only at rest 30 per cent had both weight bearing pain and rest aching but 18 per cent of these were considerably better than before the operation In all 88 per cent of the cases were found to be improved as regards pain 87 per cent manage the activity of daily life without much trouble 57 per cent have no stick but 36 per cent use one 57 per cent have returned to wage earning mostly light work but 18 per cent have returned to industry forest and agricultural work Out of the 43 per cent who have retired half manage to look after their home themselves

Clinically no change in mobility is found generally but in 70–80 per cent the malpositions are corrected

Radiologically according to conventional evaluation a joint space increased in breadth or more sharply marked is observed in 56 per cent and more or less healed cysts in 50 per cent

Conclusions

The operation seems to be a relatively simple method of halting a destructive arthrosis process lessening the patient s subjective troubles and correcting possible malpositions while mobility is scarcely affected

RESULTS AND COMPLICATIONS IN INTERTROCHANTERIC OSTEOTOMIES
by *I Goldie* & *C Hirsch* (Gothenburg Sweden)

OSTEOTOMY OF FEMUR IN PATIENTS WITH CEREBRAL PALSY
by *Ingulf Medbo* (Oslo Norway)

In an attempt to correct deformities of the lower extremities in patients with cerebral palsy a rotation osteotomy was performed in the subtrochanter region of femur in a number af patients

This paper concerns the results in 27 patients In 13 cases the operation was performed unilaterally in 14 cases bilaterally in all 41 osteotomies

In 12 patients the osteotomy was the only operative procedure in 15 patients the osteotomy was combined with soft tissue surgery

The indication for osteotomy was partly some sort of dysplasia or maldevelopment of the hip joint partly walking difficulties because of internal rotation and adduction contracture of the hip joints

The osteotomy was performed in the subtrochanter region

The lower fragment was rotated externally and fixed with one metal plate placed laterally or in the older age groups with two metal plates at a 90 angle

At the time of surgery 26 of the patients were in the age group 5–19 years and one was older than 20 years

They were followed up 1 to 10 years postoperatively on an average 2¼ years

With the operative technique used there was solid healing of the osteotomy 3–6 months postoperatively in 40 out of 41 operations In the last case a slight instability at the site of osteotomy necessitated a reosteofixation 16 months postoperatively resulting in solid healing

There were no operative complications otherwise No angulation of femur was observed at the site of osteotomy One case suffered a fracture of femur in the subtrochanter region about one year after solid healing because of falling during walking exercises

Judging from this material there seems to be no risk of delayed healing of bone or tendency to angulation at the site of osteotomy because of assymmetric muscle pull in patients with cerebral palsy

The functional effect of the osteotomy however seems to be somewhat doubtful There is therefore reason to believe that soft tissue surgery is to be preferred in patients with cerebral palsy Bony corrections should most likely be used only as c mplementary procedures and perhaps with better results in adults than in the younger age g oups

SHORTENING OF THE FEMUR by *John Hald* jr (Oslo Norway)

Femoral shortening is mostly performed on account of the unequal length of the lower extremit es The meth d of operation varies osteotomies with overriding have been used later reports have recommended resection of the femur The osteotomies have been made transverse oblique or step formed and different ways of internal fixation have been tried intramedullar nails nail plates screws Add tional fixation with plaste is widely used

Material

At our department 30 shorten ngs f the femu were performed in the years 1951 1964 17 women and 13 men Age d stribution 15–40 years aver ge 22 years

Pr operat ve Diagnosis

Sequelae fract femori	6
Sequela osteomyelit oxit gon t	6
Extremitates inferi res inequales	6
Luxatio coxae c ngenita	5
Seq iel e poliomyelit	4
Sequelae pifysiolysis ap tis femoris	2
Sequelae t l pes equino varus	1

Metho ls	Fixation	
Osteotomy	Metal sutu e	
Obl que w th o rriding	Intramedull ry nail	1
T ansverse and re ti n	Two vitallium plates	6
	One vitall um plate and one plate of cortical	8
"	homologous bone	
		15

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Ext emitates inf o e inequales	6
Luxatio coxae congen ta	5
Sequelae poliomyel t	4
Sequelae epifys oly p tis femoris	?
Sequel e tal p qu no varus	1

Meth d	Fixation	
Oste tomy	Metal suture	
Obliqu with overrid ng	Intramedullary nail	1
Tr n e e nd r tion	Two vitallium plates	6
" "	One vitallium plate and one plate of cortical homologous bone	8
		15

Postoperative fixation		Weight bearing	X ray union
None	5	11 months	11 6 months
Hip plaster spica from the day of operation	6	6 5 months	6 5 months
Hip plaster spica after healing of the operation wound	19	6 months	6 5 months

Complications

Primary non union	4
Infection	1
Refracture	1

Results

Clinical and roentgenological healing in all cases

Length difference after correction		
	0 – 2 cm	14
	2 1 – 5 cm	14
	5 cm	2

Three patients are using orthopaedic shoes

Discussion

The shortening operations were in all cases unilateral to correct different leg lengths Maximal shortening was 6 cm minimal 4 cm average 4 9 cm

In the period 1959 1964 the method of our department was a subtrochanteric transverse osteotomy resection of the femur and primary internal fixation with one vitallium plate and one plate of cortical homologous bone and sufficient screws In this way an exact shortening was obtained and the use of the bone plate added the benefit of bone transplantation

In the whole material complications were rare but the time for healing of the complicated cases was considerably increased (up to 25 months) One patient still has infection with discharge after two years Three of these patients had no plaster spica

The results were satisfactory with good function and strength of the operated extremity

Conclusions

1 *Femoral shortening is no simple procedure*
2 Resection of the femur and fixation with one vitallium plate and one plate of cortical homologous bone seems to be a good method
3 *Long hip plaster spica is needed for 4 5 months*
4 Complications are rare but their healing takes considerable time

Summary

In the period 1959 1964 femoral shortenings were performed by a subtrochanteric transverse osteotomy resection of the femur and fixation with one vitallium plate and one plate of cortical homologous bone with sufficient screws Long hip plaster spica was applied for 4 5 months The results were good the complications rare but apt to take a considerable time to heal

DISCUSSIO\

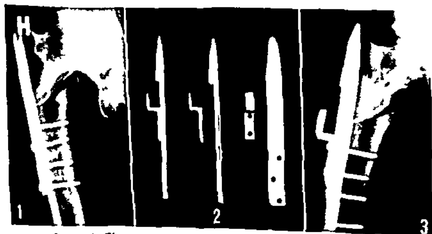
T Jerre (\asterås Sweden)

\\hen plates of current type are used in intertrochanteric osteotomies for fixation it happens now and again that the fixation is unsatisfactory because the plate obtains insufficient support medially in the proximal fragment The result is a medial displacement of the distal fragment and a \arus formation at the site of the osteo tomy (Figure 1)

This complication as a rule produces indeed no destructive effects but it is the cause of delayed healing

In order to achieve a letter fixation the author together with civil engineer Flo\ Tornros from Stille \\erner Stockholm constructed the instruments shown in Figure 2

Foll wing the customary intertrochanteric osteotomy with medial displacement of the distal fragment the plate is applied in the normal way The plate which is pointed at its proximal end is hammered in until it has certainly perforated the trochanter co ticalis By means of further hammering inward the position of the plate is finely adjusted so that the angleplate obtains the desired grip laterally of the cortex of the proximal fragment In order to ensure an exact fit the angleplate is supplied with the middle part n f e arying lengths It can be applied moreover in two p siti)ns proximally distally on the plate The angleplate should be placed so that a space of about 5 mm arises between the lower e lge of the cortex of the proxi mal fragment and the mid part of the angleplate this is in order to permit com p ession at the osteotomy site The plate is afterwards fixed to the femur with three screws and the angleplate (by means of preformed holes in the plate) by two screws pa sing through both the outer and the inner cortex of the femur The plate has been



Figur 1 The most p on un ed displacement in the author s series
Figure 2 Th in trument
Fig re 3 Case 1 (4 weeks afte operation)

made at least up to this time in one standard size only The osteotomy should be sited therefore under the guidance of the X ray picture so that the length of the plate permits its point to perforate the trochanter corticalis With a very strong skeleton therefore the osteotomy should not be made too obliquely

During the past month the author has used this instrument in three operations (Figure 3) Technically no difficulties arose and the primary fixation is very stable The patients were allowed to get up 3–4 days after the operation and then walked with full weight bearing using two crutches for support

The primary results in these three cases have been considerably superior to those achieved previously by the author when he used conventional plates of various types

H Dahl (Oslo Norway)

O Johansson (Stockholm Sweden)

L Unander Scharin (Malmo Sweden)

The indication for unilateral osteotomy are indeed pressing when taking into consideration the often considerable incorrect weight bearing which arises in the back if no corrective splint is used Corrective splints shoe elevation etc are aids which are often not accepted by the patients

The indication area for bilateral shortening osteotomy is extremely narrow

A number of methods for shortening have been reported At the Orthopaedic Clinics in Harnosand and Malmo a subtrochanteric osteotomy has been evolved in which the fixation is made with nail and plate according to MacLaughlin In this we were anxious to place the topmost nail on a level with the trochanter minor and above the osteotomy A plate with 7 holes has always been used Early getting up has been adopted without any plaster fixation Out of 20 bilateral cases operated on according to this principle only 1 case increased delayed heeling This case was supplemented by the placing of a bone graft above the osteotomy

H Storen (Oslo Norway)

Regarding the second part of Medbø's lecture The Effect of rotation osteotomy on the function of the lower extremity in these patients – then the results he has obtained confirm the old and well grounded principle that no bone operation should be undertaken in a spastic malposition until muscular balance has been achieved that is until the effect of the muscles producing the malposition is eliminated to a suitable extent At the annual congress of the Norwegian Surgical Association in 1937 I gave a lecture based on follow up investigations and direct observations in this theme (Tendon transposition in spastic conditions of the lower extremities reproduced in the Norsk Magasin for Lægevidenskapen August 1938) It has been shown that the principle maintained here and particularly illustrated in the results of operations on the feet—was a correct principle to follow not only in the case of feet but also in spastic malpositions which affect the upper parts of the lower extremities Rotation osteotomies of the femur secondary have only rarely been necessary in the relatively large number of operations of this kind which I have performed during the course of the years

If the procedure is limited to the bone operation as I have seen done and has

evidently been the case in part of Medbø's series the spastic muscles which predominate will in a large number of cases gradually bring back the malposition. A derotation then results on the femur. But soft tissue operations make special demands on the surgeon. Apart from the absolutely rational technique he must have good personal experience and every patient must be observed over a good period of time in advance owing to the variable nature of the symptoms so often present in these patients. Dr Medbø is fully correct to say that each case should be carefully evaluated preoperatively.

I hope that Doctor Medbø will continue to work on this very important and interesting subject and I believe that he will find much material on which to base future research if he studies what has been previously achieved and the experience accumulated on this subject in our own country.

E. Sanlaa (Sandvika, Norway)

H. Novotny (Oslo, Norway)

CLINICAL PROBLEMS ON OSTEOSYNTHESIS IN FRACTURES OF THE EXTREMITIES

A TECHNICAL NOVELTY: A.O. COMPRESSION PLATE AND SCREW

by *E. Moberg & G. Hansen* (Gothenburg, Sweden)

A METHOD FOR ACUSTIC REGISTRATION OF FRACTURE HEALING

K. A. Fernberger (Stockholm, Sweden)

In collaboration with M.D. *Bertil Jacobson* at the Department of Medical Electronics at Karolinska Institutet a method has been developed for measuring the transmission of vibrations through callus in healing fractures.

At the middle of tibia an electromagnetic vibrator is fixed with a nail. The vibrator is run by a tune generator to frequencies from 20–10 000 cycles/sec. One microphone (piezo-electric crystal) is fixed to the vibrator and obtains the oscillations *of the vibrator* and on the two microphones are fixed with nails the same way *to tibia* at a constant distance proximally and distally to the vibrator and these two obtain the oscillations transmitted through the bone. *The voltage of the electric current* from the oscillations transformed by the microphones will be reduced when the oscillations are transmitted through the bone and much more *when there is an* [illegible] fracture [illegible] situated between *the vibrator* and one of the other two microphones.

The electric current from the microphones is passed through three amplifiers to a three-channel recorder while the tune generator runs *from 20–10 000* cycles/sec. Meanwhile the [illegible] of the current from the microphones is controlled on an oscilloscope screen.

The spectrum of resonance frequencies and transmission variations from a patient with 6 months' [illegible] of a fracture is *demonstrated*. The loss of transmission capacity [illegible] over the fracture compared to that over intact *bone of the* same leg

and to that of the uninjured tibia of the other leg On a preparate the very slight transmission of vibrations over intact fibula is shown and the very good trans mission between tibia fragments with a minimum of cortical contact of bone

The method has to be more refined if an evaluation of resonances and loss of transmission capacity is to give exact information of the fracture stability

OSTEITIS FOLLOWING OSTEOSYNTHESIS—TREATMENT AND PROGNOSIS

by *P Thestrup Andersen* (Copenhagen Denmark)

During the period 1 8 1960 to 31 7 1965 a total of 376 osteosyntheses were performed on extremity fractures in the Surgical Department R of the Gentofte Hospital Copen hagen Among these cases 7 or 1 6 per cent of the total series developed postopera tive infections in the form of osteitis These patients were 4 males and 3 females in the age range 43-81 years

Age Sex	Cause	Type of Fracture	Primary treatment	Course
43 ♀	Skating	Uncompl comminuted fr of lower leg	Immediate osteosynthesis (Eggers method)	Staph aureus exposed osteosynth material
59 ♂	Traffic accident	Compl fr of lower leg (uncompl fr of femur and scapula)	Reduction of lower leg fr Osteosynth of femoral fracture	Non healing of lower leg fr Cerclage osteosynth with bone graft (17) Staph aureus
74 ♂	Traffic accident	Uncompl fr of lower leg (oblique fr)	Osteosynth (Lane method)	Exposed bone + splint Staph aureus
56 ♂	Fall in street	Uncompl fr of lower leg (oblique fr)	Osteosynth (Lane method)	Abscess in wound exposed splint
78 ♂	Fall at home	Subcap fr of fem neck	Alloplasty (Moore method)	Pt senile incontinent Esch coli inf in wound Died 3½ month later
81 ♀	Fall at home	Pertroch fr of the femur	Osteosynth (MacLaugh method)	Severe Staph aureus infect alarming There fore osteosynth and traction material were removed
78 ♀	Fall at home	Pertroch fr of the femur	Osteosynth (MacLaugh method)	Severe Staph aureus infect alarming There fore osteosynth and traction material were removed

One patient (a 78 year old man) died of sepsis 3½ months after alloplasty by the method of Moore Of the remaining 6 four had comminuted fractures of the lower leg and 2 comminuted pertrochanteric fractures

The principles of treatment after the infections became manifest were conservative The osteosynthesis material was not removed until the fractures were stable

After treatment consisted in long-continued splinting

Treatment with antibiotics was guided by cultures and sensitivity determinations and was continued until the skin had healed completedly and the general condition (assessed by the temperature E.S R. and Hb level) was normal

The prognosis in the cases treated here was good

One patient had died of an irrelevant cause at the time of follow up

The other 5 had no symptoms from their osteitis

In deciding the indications for osteosynthesis regard must be paid to the patient s physiological age and the type of fracture while an open fracture *per se* does not

stemic er treatment	Local after treatment	Duration of bandag	Follow up
tib otics *only* ter culture and ns tivity determ	Plaster cast splint removed 5 mo afer removal of sequestrum	1 year 9 months	2 years later Fit
tibiotics *only* ter culture and nsitivity determ	Plaster cast Osteosynth material + sequestr removed 8 months later	1 year 4 months	1½ years later Fit
nt biotics *only* ter culture and nsiti ity determ	Plaster cast Splint not removed	3 months	4 years later Fit
ntibiotics *nly* ter culture and nsitivity determ	Splint removed 3 mo later fr healed	3 months	4 ½ *years.* Fit.
ntibi ti s *only* fter culture nd nsitivity determ			
ntibioti s *only* ft r culture and nsiti ity d term	Remo al of osteosynth mater 3 mo l ter Drain ge Remo al of seq iestr Tra t on	Bed rest 8 months	Healing w 7 cm shortening Walks with 2 Engl sh canes
ntibi ti s *nly* ft r culture and nsitivity d term	Remov l of osteosynth m t 1 mo l ter D ainage traction	8 m nth *Bed rest* 4 months F act and wound healed	Had died of irrelevant c use

contra indicate surgery. In the case of elderly debilitated patients with severe comminuted fractures it is well to make the indications strict.

DISCUSSION:
O. Lindahl, K. Moberg, F. Madsen, K. Solheim, I. Palmer, A. Jernberger, S. Friberg, C. Hirsch, H. M. Dencker

EARLY DIAGNOSIS OF INTERPOSITION IN FRACTURES WITH THE AID OF A VIBRATOR by *Hans Dencker & Erik Moberg* (Gothenburg, Sweden)

It is important in definitive treatment of a fracture to ascertain at an early stage whether the healing process is hindered by soft tissue interposition between the fracture ends. Considerable observation time may be lost before the situation is clarified. To simplify the problem a vibrator has been constructed with which interposition can often be definitively diagnosed.

A schematic diagram of such an apparatus is given in Figure 1. It consists of a vibration generator, an amplifier and a measuring instrument. A tone is produced by the generator at a frequency of 1000 Hz and a transducer is employed to convert the sound to mechanical vibrations. The vibrations transmitted through the bone are taken up by a receiver which varies with the size of the vibrations. The amplifier is composed of a function and sensitivity selector and of a filter which eliminates irrelevant vibrations. The apparatus is fitted with a logarythmic amplifier which simplifies the measurements.

With normally healing bone and with fractures having contact of the ends of the bone the vibrations are always conducted at a level giving measured value of more than 70. With interposition of soft tissues considerably lower values, not more than 30, are obtained. Low values (< 30) always mean interposition while high values (> 70) do not always indicate that the contact between the broken ends is sufficiently good to obtain satisfactory fracture healing within an acceptable time because only minor contact is adequate to conduct the impulses at full level.

The vibrator is particularly useful with fractures of the femur or humerus. With forearm and lower leg fractures the method is not as reliable; the presence of interposition can be hidden by conduction of the impulses via an intact bone or a bone which permits transfer through the fracture region.

To summarize: Interposition with regard to femoral and humeral fractures can be definitively diagnosed with the described vibrator.

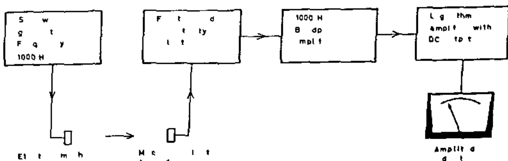


Figure 1. Schematic diagram of the vibrator.

FRACTURES OF THF FEMUR

FIXATION OF FEMORAI SHAFT FRACTURES BY TWO STRONG VITAI LIUM PI ATES by *E Madsen* (Sorø Denmark)

Fractures of the shaft of the femur (28 transverse 6 comminuted and 1 oblique) have been treated by fixation with 2 strong vitallium plates placed laterally and anteriorly on the shaft and each fixed by 4 vitallium screws with a good hold on the cortical bon This fixation is so solid that active mobilisation can be started at once The method Is preferred to Kuntschner s nailing where fixation is often in sufficient particularly in preventing small rotation movements Poor fixation may result in delayed union shortening and angulation and there is a risk of bending or breaking of the nail Furthermore should infection complicate nailing it will tend to be serious and invalidating

These possible complications have been avoi led using ? strong vitallium plates 35 cases have been followed up

Results

Ideal	?4 cases
Good	7 cases (knee 180/40–65 normal gait and working ability)
Fair	2 cases (knee 180/40–80 shortening 0–1 cm angulation 0 3)
Bad	2 cases (knee 180/50–130 shortening 0–1 cm angulation 0 3)

There was only one case of shortening (1 cm) and one case of angulation (2 3) There were no cases of infection

Heal ng tim		
	1½ – 2 months	20 cases
	2 – 3 months	8 cases
	3 – 4 months	5 cases
	4 – 5 months	1 case
	5 – 6 months	1 case

FEMORAL SHAFT FRACTURES by *A Solhe m* (Oslo Norway)

In the 10 year perio l 1955 1964 242 patient w th femoral shaft fractures were treated at Surgical Department III Ullevål H sp tal Oslo Norway The majority of the patients over 20 years of age w s treated with operative reduction internal fixati n and ea ly ti mobilization (Figure 1)

I lating was the mo t common procedure employed (Table 1) All deaths amongst the perated p t ent wer due to I ronchopneumonia and cardiac *failure in* old patients The e w s no d ath of embolism or e ere thrombo embolic complication in the p t ly treated group while 4 patients died sud lenly of pulmonary em I lism r f t emboli m n the group treated with *traction only The 6 other* deaths in the traction gr up we e due to other inju ies Only one case of arterial injury was enc untere l tre t d ucce fully with intimectomy"

The pat ent w re in most ca es treated by til l traction befo e operation (Table 2) No a of infection was encountered amongst the open fractures

The plating w upplemented with wiring in some cases and two plates were used

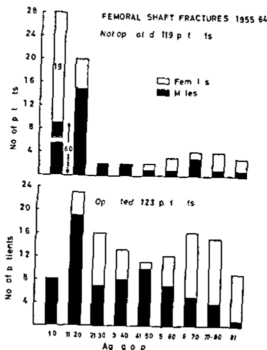


Figure 1

Table 1 Femoral shaft Fractures 1955–64

	No of pat	Deaths	Osteomyel	Re op	Removed plate etc
Plating	72	3	1	7	11
Wiring	19	2	1	2	6
Nailing	16	1	–	–	7
Suture	14	–	–	–	1
Others	2	–	–	1	–
Traction	119	10			

in 11 patients one laterally and one anteriorly placed (Table 3) In the one case complicated with osteomyelitis the infection subsided when the plate was removed

Six patients had to be re operated in four this was due to fracture of the plate and in two due to non union All these patients were successfully treated by new plating with two plates and autogenous transplantation of cancellous bone Nail plating was used in some cases of fractures through the upper and lower part of the femoral shaft with the nail in the caput femoris or in the femoral condyles respectively

Of the 72 patients treated with plating and mobilization immediately after the operation 63 were followed up 7–90 months postoperatively Nine were dead In 3 cases the result was not good (poor knee joint function) Two of these patients

however were operated after 3 months in skeletal traction In the remaining 60 patients the anatomical and functional results were excellent

Table 2 Femoral shaft fractures 1955–64

	No	Time injury – oper
Plating 72 patients		
9 open	7	mean 22 days (7–56 days)
	2	12 and 19 weeks
63 closed	2	immediately
	59	8 days (?–28 days)
	2	12 weeks

Table 3 Femoral shaft fractures 1955–64

	Osteomyel	Re-op	Removed plate etc
37 plati g (one pl te)	–	6	5
7 plating and wiring	–	–	–
13 nail plating	1	–	4
4 nail and wi ing	–	–	1
11 plating (two plates)		–	–

OSTEOSYNTHESIS WITH A THICK MEDULLARY NAIL IN NON UNION OF LONG BONES by *L E Laurent* (Helsingfors Finland)

The mate ial onsists of 26 cases of non union located in 1? cases in the tibia in 8 case in the femur in 4 case in the humerus and in ? cases in the r dius and ulna re pectively The medulla y ca ty was reamed out with the aid of hand burrs and a pneum tic burr The pseudarthrosis was then fixed with a thick medullary nail The diameter of the nail was 14 16 mm in the case of non union of the femur in non union of the t bia 11 15 mm of the humerus 11 14 *mm and of the* radius and the ulna 6 mm Open operation was ried out in all cases except in two of non union f the tibia when closed nailing w s performed In 10 cases the osteosynthesis was c mpl ted w th a free bone graft The method seems to *be very suit ble* in cases of n n union of the haft of the femur or the tibia permitting mobilisation and weight bearing very o n aft r ope tion Immobil sat on in a plaster cast could be avoided in all es of non union of the femur In six of the cases of non union of the tibia a walking pla ter c t was u ed f r six weeks Th method was less suitable in the c se of non uni n of the humerus because the nail loosened and the head of the n il caused irritation of the shoulder joint

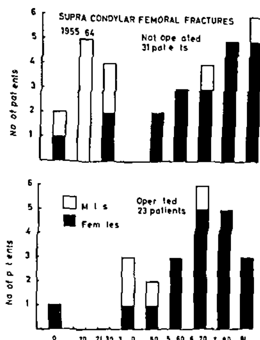


Figure 1

SUPRACONDYLAR FEMORAL FRACTURES by A *Solheim* (Oslo Norway)

In Surgical Department III Ullevål Hospital Oslo Norway 54 patients with supracondylar fracture of the femur were treated in the 10 year period 19 5 64 (Figure 1) The non operated patients were cases without dislocation of the fracture or in a few cases patients in too a bad condition for operation The majority of the

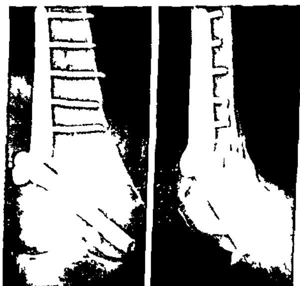


Figure 2

patients were elderly women and this has an important bearing on the choice of the method of treatment Most of them have osteoporotic bones and furthermore they will not tolerate a lengthy immobilization We therefore treat this fracture with open reduction internal fixation with a McLaughlin s nail plate and early mobilization The threeflanged nail is placed through the femoral condyles and this gives a good fixation also in cases where the condyles are dislocated from each other After reduction the plate are screwn tight to the nail and fixed to the femoral shaft with screws engaging both cortices (Figure 9) In this way a firm fixation of the small distal fracture fragment to the proximal is secured permitting early mobilization

Table 1 Supracondylar femoral fractures
Results

Excellent 17 patients	Gate normal No pain Extension normal Flexion at least 120
Fair 2 patients	Some pain Use stick Extension normal Flexion 35 and 90

Observation time mean 16 months (6–3 months)

With this method ? patients were treated Only one case of arterial injury was encountered successfully treated with intimectomy" There was no case of post operative death but one case of non fatal pulmonary embolism and 3 cases of wound infection one of which was severe requiring removal of the nail plate

In 3 patients redislocation occurred in one case due to fracture of the plate and in a further two cases re operations were performed due to increasing valgus deformity The further course in these 3 patients was uneventful Some patients experience pain over the nail head due to a bursa forming In 6 patients these troubles required the removal of the plate nail

The results of the treatment of this difficult fracture along the above mentioned lines have been very satisfactory (Table 1)

DISCUSSION

F Moberg G Din kw rll Lillieström P Slatis

FRACTURES OF THE LOWER LIMB

STABLE OSTEOSYNTHESIS A M KÜNTSCHER IN THE TREATMENT OF FRACTURES OF THE CRUS by *P O Cronblom* (Vasa Finland)

Immobilisation of fractured extremities has its disadvantages Although quite good results in fracture healing can be obtained there are such drawbacks as heavy plaster casts restricted motion muscle atrophy permanent joint contractures and as a result of all this mental strain Stable osteosynthesis a m Küntscher where a thick medullary nail is used does not require immobilisation at all and the patient can tread on the fractured leg while the process of healing is going on

In the Central Hospital of Vasa Finland fractures of the crus have been treated by the technique since 1960 In this report only the earliest cases 32 in number with an observation period of more than four years on an average have been considered

The duration of treatment in hospital was 2¼ weeks Mobilisation of the joints was begun as soon as the pain in the wound was relieved and when discharged from the hospital all these patients walked with the aid of crutches and began partial weight bearing After 2¼ months the crutches were abandoned In some cases the patient was able to walk without support two weeks after the osteosynthesis

Complications accompanying the osteosynthesis itself are splinters in either of the fragments when the nail is hammered in The ream may also make a score in the cortex and in these cases plaster casts have been applied to avoid complications in connection with weight bearing The point of fracture was opened and open reduction was made in five cases There was no infection in this group

A follow up of the material 4–5 years later shows no restriction worth mentioning in the functions of the knee and ankle joints No later fistulations or refractures were reported

From experience gained from complications and from the point of view of advantages it may be concluded that the technique is very good in a selected osteosynthesis material If the fractures of the tibia are too low down or in case of long spiral fractures this method is not convenient The medulla nail should be as thick as possible at least 12 mm in diameter and sufficiently long to ensure stability The place of entry should be as high up on the tibia as possible to give the medulla nail bending elasticity and to diminish the danger of splintering The nailing should preferably take place at once but in cases of infected open fractures not until the risk of infection has been eliminated X ray control is necessary for successful osteosynthesis The length and thickness of the medulla nail should be carefully measured before operation If the osteosynthesis fulfils the requirement of stability this permits a certain amount of weight bearing after 2 weeks and the patient can return to work long before consolidation has taken place

INTRAMEDULLARY NAILING OF TIBIAL SHAFT FRACTURES A COMPARISON WITH CONSERVATIVELY TREATED CASES by *P Slätis* & *I Rokkanen* (Helsinki Finland)

The series consist of 32 fractures of the tibial shaft in 31 patients treated with intramedullary nailing In all cases the operation was performed within 6 weeks after the fracture The intramedullary canal was reamed out and a heavy nail introduced through the tibial tuberosity using a closed nailing technique

The fractures were classified according to the trauma mechanism degree of primary dislocation degree of comminution and severity of soft tissue injury From a series of 1?? conservatively treated tibial shaft fractures 53 fractures/5? patients with a comparable type of fracture and soft tissue injury were extracted for comparison with the nailed material The conservatively treated control group included 10 fractures subsequently bone grafted due to delayed union

The results of treatment in the two groups 1 year after the accident were evaluated There were no clear-cut differences in walking and working ability between the nailed and conservatively treated cases Of the nailed cases 84 per cent had resumed work compared with 87 per cent in the conservatively treated group (including the grafted cases) The best results of intramedullary nailing were obtained in fractures with slight displacement no comminution and only slight tissue injury if any The indications for intramedullary nailing of tibial shaft fractures should be limited to cases where fracture retention proves difficult with plaster and/or where the fracture is complicated by superficial soft tissue injuries Intramedullary nailing has no place as a routine procedure in the treatment of tibial shaft fractures

OSTEOSYNTHESIS AND SOFT TISSUE INJURY IN FRACTURES OF THE SHAFT OF THE TIBIA by *Per Edwards* (Malmo Sweden)

My conclusions were based on data from 492 fractures of the shaft of the tibia in adults treated in Malmo General Hospital 1949 63 and on observations from more than 3 500 fractures surveyed from the literature The former gr up consists of a contr l eries (311 fractures 1949 60) and a prospective series (181 fractures 1961 63) The technique of osteosynthesis was discussed with regard to three types of fracture—l ng oblique closed and open transverse or comminuted fractures Special attention was paid to the development of osteomyelitis The two series diffe in that in the prospective series particula attention was paid to associated skin lesi ns with the ol ject of preventing bone infection The frequency of osteosynthesis in the diff ent types of fracture was s milar in the two eries In the prospective series blind nailing was performed to a la ge extent in transverse and comminuted *fra tur* nd primary transplantation of skin was carr ed out in fractures with large w und The foll wing onclu ion ould be mad

1) There is a clo e relationship l etween kin necrosis and osteomyel tis

2) I ng (l que fra tu es are well uited f r open reduction and internal fixati n There i a minute ri k f complications from this treatment

3) In losed t an verse an l comm nuted fracture treated with open reduction there i high frequency of c mplications—o teomyelitis in m re than 10 per cent. Clos l method in lu ling blind nailing should l e preferred

4) In p n transv r nd c mminuted fractures whether treated by osteosynthe i r n t ther i high inciden e of omplications—18 per cent of osteomyelitis in th nt ol eri O t omyeliti can to a large extent be prevented if skin incisions a e a il l in th fr tu rea an l primary skin transplantation performed when ne d t l n if a fully t ble fixation is not attained osteosynthesis may increase th ct nc of ce ful k n grafting

Ref nce Per F lw rds (196) Fractu e of the Shaft of the Tibia 49? Consecutive C s s in Adult Import nce f s ft ti sue injury *Acta orthop scand* Suppl 76

CERCLAGE IN FRACTURES OF THE TIBIA by *K F Hagelin* (Sweden)

DISCUSSION

I Moberg C Hirsch S Olerud H Nissen Lie P Edwards E Thomasen
V Oram O Lindahl K Dohn

FRACTURES OF THE RADIUS AND THE ULNA

FRACTURES OF THE RADIUS AND THE ULNA TREATED BY A SPECIAL METAL PLATE by *P Forssblad* (Gothenburg Sweden)

DISCUSSION

E Moberg C Hirsch F Madsen I Palmer V Oram K Solheim S Olerud
H Heikel P Forssblad R Movin F Thomasen P Slatis I Hagelstrom I Ahik

VARIA

A SIMPLE METHOD OF TRANSFIXATION IN ANKLE JOINT FRACTURES
by *H S Mattsson* (Sweden)

OSTEOSYNTHESIS IN CLAVICULAR PSEUDARTHROSIS
by *Knud Jansen* (Copenhagen Denmark)

Non union of clavicle fractures occurs in approximately 0 1 per cent Forty cases were referred for treatment to the Orthopaedic Hospital of Copenhagen within 15 years

Thirteen cases were treated by physiotherapy three by resection and seventeen by osteosynthesis with bone graft screws Kirschner wire or cerclage Five out of twelve cases were healed by one operation one out of four was healed after two interventions and one case was operated thrice without success

Total failure 11 out of 17

A new process has been applied in eight cases one of which had two earlier operations

Technique

Incision parallel to one half inch inferior to the clavicular bone Incision of periosteum and subperiosteal dissection of bone ends Resection of sclerotic bone ends (⅓–¾ inch)

Fixation by a threaded Steinman pin which by an electric drill is passed retrograde into the medial part perforating the anterior cortex medially After approximation of bone ends the pin is drilled past the fracture line and into the lateral fragment until stability has been achieved (one to two inches) and the pin is cut leaving one inch free subcutaneously A cortico cancellous bone block (approx 2 by

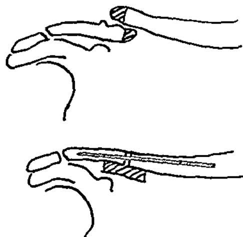


Figure 1



Figure 2

$\frac{1}{2}$ by $^{3}/_{8}$ inch) i t k n f om the ilium and fixed below the fracture by a heavy silk utu e which is pla l longitudinally and pas e l thr ugh vertical drill holes in graft an l lavi le The utur i tightened by pushing wedge hape l bone pieces between th e d and upper urfac of the bone

I eri steum pl ty ma and skin re sutured

A pl ster sh ul l r pica is applied for 12 weeks The application may be post pone l until the 3rd or 4th post perative day

CERCLAGE IN FRACTURES OF THE TIBIA by K F *Hagelin* (Sweden)

DISCUSSION

L Moberg C Hirsch S Olerud H Nissen Lie P Edwards E Thomasen N Oram O Lindahl K Dohn

FRACTURES OF THE RADIUS AND THE ULNA

FRACTURES OF THE RADIUS AND THE ULNA TREATED BY A SPECIAL METAL PLATE by *P Forssblad* (Gothenburg Sweden)

DISCUSSION

E Moberg C Hirsch E Madsen I Palmer N Oram K Solheim S Olerud H Heikel P Forssblad R Movin E Thomasen P Slatis I Hagelstrom I Alrik

VARIA

A SIMPLE METHOD OF TRANSFIXATION IN ANKLE JOINT FRACTURES by *H S Mattsson* (Sweden)

OSTEOSYNTHESIS IN CLAVICULAR PSEUDARTHROSIS
by *Knud Jansen* (Copenhagen Denmark)

Non union of clavicle fractures occurs in approximately 0 1 per cent Forty cases were referred for treatment to the Orthopaedic Hospital of Copenhagen within 15 years

Thirteen cases were treated by physiotherapy three by resection and seventeen by osteosynthesis with bone graft screws Kirschner wire or cerclage Five out of twelve cases were healed by one operation one out of four was healed after two interventions and one case was operated thrice without success

Total failure 11 out of 17

A new process has been applied in eight cases one of which had two earlier operations

Technique

Incision parallel to one half inch inferior to the clavicular bone Incision of periosteum and subperiosteal dissection of bone ends Resection of sclerotic bone ends (⅓ ½ inch)

Fixation by a threaded Steinman pin which by an electric drill is passed retrograde into the medial part perforating the anterior cortex medially After approximation of bone ends the pin is drilled past the fracture line and into the lateral fragment until stability has been achieved (one to two inches) and the pin is cut leaving one inch free subcutaneously A cortico cancellous bone block (approx 2 by

The arm was placed in an abduction splint for 6 weeks—but passive exercises of shoulder and elbow joint were carried out daily After 8 weeks he commenced active movements After 6 months the cerclage wires were removed as they showed a tendency towards eroding X ray showed at this time abundant bone f rmation He was now allowed to take up light work The treatment result was full mobility of the shoulder jo nt—no muscle atrophy and both shoulders equally abroad The two Rush pins have not been removed. He walks with them now after 9 years and has no difficulty with them He has been employed full time as a heavy worker during the whole period There is a fundamental difference between this method and Nicoll s—an *a tive* pre sure is exerted in my method by the two fragments towards the trans plant from both si les

This case is described in *Acta Chir Scandinav* 13? 243–247 1966 Operative Correction of Clavicular Defect A new surg cal method

FRACTURA COLLI FEMORIS—THE STEEL NAIL
by *John Sp toft* (Kalundborg Denmark)

Fracture colli femoris is an increasing me lical social problem The number of cases has redoubled in the course of ten years and soon ten per cent the l eds in a general surgical ward will be occupied by these fractures

As long as the treatment is not centralized the simplest method yielding good results is to be recommended

This is a three falanged nail placed very steeply resting on the medial c llum c rtex and fixed in the firm caput so as to slide down into trochanter concurrently with the collum resorption In this way there will constantly be a functional pressure at the site of fracture so that healing will be facilitated

In the cou se of 20 years this method has resulted in my hands in more than 95 per cent healing and very few re operations

A NEW NAIL FOR TREATMENT OF MEDIAL FRACTURES OF THE NECK OF THE FEMUR by N *Rydell* (Gothenburg Sweden)

RESULTS OF OPERATIVE TREATMENT WITH CERCLAGE IN TRAUMATIC RUPTURE OF THE PUBIC SYMPHYSIS
by *Ak Gu taf s n* (Link ping Sweden)

The g up c n i t of 8 patients with traumatic lesion of the pubic symphysis The materi l consi t of patients treated 1960 65 at the S hlgrenska hospital Gothenburg The pati nts were treate l perativ ly by cercl ge of the ruptured symphysis Th c clage wi e w s put th ough the foramina obtu atoria instead of as usual through d ll holes in the os pubis By this modificat on no cutting through of the bone wa cen t occu The r ults oul l be followed up in 6 p tients and were n ur gingly g o l Compared with the results of nonoperative treatment published in the literature there is a shorter period of bed re t and a much shorter period for return to or linary w rk. Operative fixation in the e lesions by me ns of cerclage through the f ramina obturat ria is therefore rec mmended

Problems

1) The selection of pin size should be made by evaluation of the bone diameter
2) By bone drills should be omitted as this may damage the bone cortex
3) The plaster bandage period was in one case *reduced to 6 weeks In spite of* promising X ray findings pain and superfluous callus formation indicated a new bandage 6 weeks later and union was achieved

Complications Wound drainage occurred in two cases Both healed after local revision

3 pins were removed later the indication being soreness at the medial subcutaneous *end of the pin*

Results In all eight cases solid union was achieved

One case had slight acromio-clavicular symptoms Otherwise all patients had relief and restoration of function

DISCUSSION

H Storen (Oslo Norway)

From observing the work of the orthopaedic clinics alone one easily gains the impression that clavicular pseudarthroses occur more rarely than is in fact the case I have the impression that in Norway a large number of our general surgical departments have had experience of a case from time to time—and they can on the whole demonstrate good results from the various methods employed Lane s plate and thin *cortical tibia transplants often seem to be used but correctly inserted metal* wire sutures with tibia transplant seem to have given equally good results In the unsuccessful cases which I have received for reoperation technical errors during operation or during postoperative treatment have existed When resection of the outer clavicular end is involved then in each case this (in my opinion less favourable) treatment ought not to extend medially of the coracoclavicular ligaments

More difficult than the simple clavicular pseudarthroses are the defect pseudarthroses

The ideal aim in treating these is firm healing without shortening and prevention of damage to the function of the shoulder joint during lengthy immobilisation This was achieved by the following procedure in a transport worker aged 47 who had been unable to work for more than a year due to a 3–4 cm large defect in the *mid* part of the clavicle *following* removal of an intermediate bone *fragment owing to* pain after a clavicle fracture The pain was almost absent after the removal but the arm was powerless—he could not support himself on it and he could not resume work

The sclerotic bone ends were resected by means of a normal intraclavicular *longitudinal incision A Rush pin was introduced from the medial* side and one from the lateral side through holes drilled in the medullary cavity with an *awl Two* T shaped tibial transplants were made so that the vertical thick section —consisting of periosteal cortex cancellous bone—corresponded to the gap between the two bone ends when they were maximally separated from each other This section was then pressed into *the defect* in this position and the horizontal wings of the T adjacent to the chiselled off upper surface of the clavicle were fixed to these by cerclage After this the shoulder joint *could be moved without causing movement* at the fracture site

Objective improvement has been stated to occur after an increase of abduction and forward elevation more than 30 degrees a backward elevation of 30 degrees and an ability to get the operated arm close to the thorax in adduction The functional results are shown in Table 2

Table 2

	Functional improvement in %	
	Subjective	Objective
Causes of operation		
Polio myelitis	68	100
Fracture nerve injury	70	70
Pains stiffness	45	8?
Rest	89	89
Total	70	91

INDICATION AND TECHNIQUE IN HIP JOINT ARTHRODESIS

by *Nils Lindström* (Harnosand Sweden)

Indications f r arthrodesis exist in

1 Inval dising unilateral complaints
2 Bilateral ch nges with light changes on the one side
3 Severe bilateral hang s where arthroplasty is contemplated on the one side
4 Pareses as a stabilising operation

The ba k must l e clinically an l radiologically satisfactory the patient must have free m bilit in the knee joint without arthrosis changes the patient s occupation must n t be hin lrance and the age limit should l e 60 65 years

In general there are two types of arthrodesis operation extra articular an l intra rt cular The former is nly u ed exceptionally in cases other than tuberculous and arthrit c ffe ti n but has l ecome f great importance as a complement to intra rti ula arthr deses

Previ u c nventi nal arthro l e p oduce l a large percentage of pseudarthoses n l th lengthy t p t e l laster immobilisation had a deleterious effect not nly n the m bility of the knee l ut l o involved greater risk for these generally lderl p opl The re ult impro e l after Watson-Jones pointed out in 1934 that it w s imp ible t achiev f ati n in pl ster alone and introduced internal fixation

St n hft H & Caballaro (19 0) re nted 117 hip Joint arthrode es due to lesions tl r th n tl with 3 p r cent p eudarthr ses an l *Stinchfiel l* (195?) 108 cases of rthr d f rman with ?? r cent p eudarthroses *R binson* publishe l 120 cases n 1J h pt at l n l s W t n J nes h m elf with 94 per cent l n ankylosis *Mar l ng* 19 8) 500 c with 8 per cent bone heal ng and *Me le d Aub gne* (1964) 90 th 84 r e nt prim r l one h aling

In ll th tl er w l ngthy plaster fixation an l as I considere l it de irable t i l thi fix t n l e olve l my own meth l in 1947 an l have used thi since th n lt on t f arti l intr and juxta articular arthrodesi with an ileum gr ft multane u nailing with a three flanged nail The patients are all wed

DISCUSSION

P Holstein I Palmer K Jansen E Moberg H Storen C Wiberg R Movin S Friberg I Alvil A Nachemson K Haug N Rydell H K Dahl

ARTHRODESIS

ARTHRODESIS OF THE SHOULDER A CLINICAL EXAMINATION

by *Karl Erik Olsson* (Karolinska Sweden)

68 shoulders were operated on with arthrodesis at the Orthopaedic clinic of Karolinska Institutet Stockholm between 1941 and 1966 The reasons for the operations are seen in Table 1

Symptomatically the operations were performed because of paralysis in 56 cases stiffness in 5 and pains in 7 cases There was contraction power before the operation in the muscles of the shoulders in all patients All shoulders were intraarticularly fixed 34 per cent without and 66 per cent with screw or nail The former group is most represented in the younger ages before the epiphysis line closed It was not proved if the different methods of osteosynthesis have anything to do with the growth of the arm after the operation

The fixation of the humerus to scapula at the operation in abduction forward elevation and rotation ought not to be the same in every cases The position must be judged with regard to the strength in the muscles of the shoulder the mobility of the elbow joint and the future use of the arm

Roentgenologically 87 per cent of the arthrodesis healed at the examination in 1966 Of the rest 85 per cent seemed to be functionally improved because of the increased stability in the shoulder from the fibrous callus

The ability to reach the mouth and the back of head with the hand of the operated arm and to dress for instance to pull down the shirt everything without pain these are all taken as signs of subjective improvement

Table 1

	Number		Total	% of the mat
Causes of operation				
Polio myelitis	15	30	45	66
Fracture	1	10	11	16
Nerve injury	–	3	3	4 5
Arthritis arthrosis	2	1	3	4 5
Tuberculosis	1	1	2	3
Congenital paralysis	1	3	4	6
Total	20	48	68	
% of the material	29	71		100

RESULTS OF ARTHRODESIS OF THE KNEF JOINT

by *P Salenius & R Kivilaakso* (Kristinestad Finland)

At the orthopaedic hospital of the Invalid Foundation in the period 1946–1965 arthrodesis of the knee was performed on 106 patients 59 of whom were men and 47 women In no case was arthrodesis performed bilaterally The youngest patient was 15 years of age and the oldest 76 The longest observation period was 20 years and the shortest 1 year 100 patients submitted to follow up examination and in*formation is lacking in respect of 6 patients only*

The main indication for arthrodesis was tuberculosis of the knee Among the after effects of polio an instabile joint which hindered walking indicated the neces sity for arthrodesis Pain after fracture was the result of secondary arthrosis 7 such ca es re ulted from gun hot wounds 5 fr m accidents at work and one only from a traffic accident Among other reasons may be mentioned the after effects of osteitis an l injury to soft tissues of the knee region where faulty position or instability were indications for arthrodesis

I ur main methods were used for arthrodesis of the knee joint, and of these the *Charnley method was used on 53 patients the largest group In 17 cases two* spongio a screv s placed crosswise over the arthrodesis area and reaching to the opj)site condyle of femur or tibia were used In 9 cases two metal wire coils were placed at the ends of opposing tibia and femur and the resected surfaces pressed together with a third coil between Operation was performed in 27 cases without internal metal fixation

Table 1 shows the methods used and the consolidation times achieved

Table 1

Method	No of cases	Consolidation under 3 m	3 6 m	over 6 m	Fibrous union	No information
Ch rnley	53	35	11	3	3	1
Screw fixation	17	5	5	5	2	–
Metal wire	9	2	4	1	–	2
No fixation	?7	4	3	10	7	3
Total	106	46	23	19	12	6

Six p tients experienced low back pain Three c mplained of pain in the ankle after prol nged walking and two of pain in the hip on same side

Of fil rous union ca es rearthrodesis was *performed on ten* and in nine of them cons lidation followe l One remained unsuccessful

The e w re 12 ca es of necro is t the edge of the wound this was cured without tre tm nt and di l not del y reco ery In one case a more prolonged infection arose in the rea of rthrodesi and wa cured later In three patients infection neces sit te l amputation from the thigh Two cases of temporary peroneal paresis oc curr d and two of arterial thrombosis

The f llow up examin tion showed th t arthrodesis of the knee joint was indicated when pain inflammati n or instability as a result of paralysis made walking dif

to lie free in bed and to get up and put weight on the leg as a rule after 6 weeks

During the years 1947–1965 I myself operated on 84 cases 2 died post operatively 1 from an embolism and 1 from shock the obduction showed tb gland suprarenal 1 patient died of carcinoma hepatis so early after the operation that the result could not be evaluated 81 patients remain therefore of which 78 achieved primary bone ankylosis and a further 1 after reoperation This produces figures of 96 3 per cent primary bone ankylosis and 97 5 per cent after a re operation Free mobility in the knee joint existed in 72 cases a further 7 had more than 90 degrees flexion and only 2 below 90 degrees flexion 75 of the patients had been working 7 at lighter work 49 at office or industrial work and 19 in heavy work

The operation is thus capable of giving good results with a large percentage of bony ankylosis and good mobility in the knee joint after a brief period in hospital

DISCUSSION

I Unander Scharin (Malmo Sweden)

It should be a sound principle that the best possible fixation is to be obtained in hip joint arthrodesis whether by using Lindstrom s three flanged nail or the screw and plate adopted by Ivar Alvik or Kalen s three point fixation with Nystrom nails My experience is almost exclusively restricted to Lindstrom s method of fixation It is very important that fully effective compression is achieved If this compression is obtained the prospect of early getting up can be considered preferably without plaster fixation as this must be regarded after all as significant weight bearing

The reason for getting the patient up early is not only lack of accommodation and a general feeling that it is important to get the patient mobile Research has been carried out by *K Rodahl N C Birkhead J J Bli ard B Isselut Jr C F D R Pruett* Physiological Changes during lengthy bed rest These authors who kept quite healthy individuals in bed discovered 1) reduction of heart volume 2) striking orthostatic hypotension 3) diminished work capacity on the cycle ergometer 4) increased calcium excertion

Similar findings have been made by other authors also The calcium excertion is said to be caused by amongst other things lack of use of the long bones and to contribute to a general osteopenia This argues in favour of the desirability of early getting up

At the Orthopaedic Clinic in Malmo getting up early without plaster fixation after hip joint arthrodesis was put into practice in 7 cases Early getting up is considered to mean after approx 10 days The series comprises 7 patients 6 of these healed without complications

The pre conditions for such a measure are that 1) the patient has a good bone skeleton that is no osteopenia or other sign of deficiency in the skeleton 2) that the patient is fit enough so that full collaboration can be expected 3) that the staff is fully informed of the whole procedure so that there is no carelessness 4) that the nail is fixed in an absolutely satisfactory manner

INVESTIGATION OF THE STABILITY OF EXPERIMENTAL HIP JOINT ARTHRODESIS by *R Kalen* (Stockholm Sweden)

RESULTS OF ARTHRODESIS OF THE KNEE JOINT

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Four main methods were used for arthrodesis of the knee joint and of these the Charnley method was used on 53 patients the largest group In 17 cases two spongiosa screws placed crosswise over the arthrodesis area and reaching to the opposite condyle of femur or tibia were used In 9 cases two metal wire coils were placed at the ends of opposing tibia and femur and the resected surfaces pressed together with a third coil between Operation was performed in 27 cases without internal metal fixation

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No fixation	27	4	3	10	7	3
Total	106	46	23	19	12	6

Six patients experienced low back pain Three complained of pain in the ankle after prolonged walking and two of pain in the hip on same side

Of fibrous union cases rearthrodesis was performed on ten and in nine of them consolidation followed One remained unsuccessful

There were 12 cases of necrosis at the edge of the wound this was cured without treatment and did not delay recovery In one case a more prolonged infection arose in the area of arthrodesis and was cured later In three patients infection necessitated amputation from the thigh Two cases of temporary peroneal paresis occurred and two of arterial thrombosis

The follow up examination showed that arthrodesis of the knee joint was indicated when pain inflammation or instability as a result of paralysis made walking dif

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INVESTIGATION OF THE STABILITY OF EXPERIMENTAL HIP JOINT ARTHRODESIS by *R Kalén* (Stockholm Sweden)

patients with ankle arthrodesis had painless but decreased movement in the subtalar joints while on the other hand the Chopart and midtarsal joints revealed increased mobility The patients with a small equinus degree were much dependent on this movement in the sagittal plane Patients with subtalar fusion complained of difficulties in walking on uneven ground 28 belonged to the group "excellent" 21 good" 5 "fair" and 8 "poor"

Summary and Conclusion

93.1 per cent have regained their working ability and 79 per cent of the patients to the groups excellent and good In walking with shoes a limp was absent in 80 per cent Without shoes limping was more frequent especially if the equinus position exceeded 15 degrees

In ankle fusion the heel should be placed in the 0 position or in slightly valgus An equinus of 5 degrees is considered generally to the best position for a man and 10 degrees for a woman

The development of secondary arthrosis is slower after ankle than after calcaneus injuries Patients with considerable pain and walking inability after calcaneus fractures need a triple arthrodesis within the first year

The disadvantages of an arthrodesis are rather small as compared to the preoperative complaints

POST TRAUMATIC ARTHROSIS IN ANKLE AND FOOT TREATED WITH ARTHRODESIS by *A Langenskiold* (Helsingfors Finland)

THE TREATMENT OF SCOLIOSIS by *Erik B Riska* (Helsingfors Finland)

The material comprises 60 patients 40 of them girls and 20 boys treated at the Orthopaedic Hospital of the Invalid Foundation in Helsinki during the period 1962-1965 Of these patients 26 had idiopathic scoliosis 24 paralytic scoliosis after polio and 10 scoliosis of other origin Eight of these 10 cases had congenital malformations of the spina In 35 cases the scoliotic curvature was localized in the thoracic spine 19 patients had a thoracolumbar curve In 27 cases the deformity exceeded 60 degrees

Table 1 Incidence of pseudarthrosis
Idiop thi paralyt c and miscellan ous scoliosis

Type of bone added	Cases	Pseudarthroses No	Per cent
Banked autogenous tibial bone	10	3	30
Autogenous tibial bone kept in the pan r 1 2 hours	17	7	41
Fresh autogenous tibial bone	33	1	3
Total	60	11	18
Bone bank bone treated before 1962	96	31	32

ficult for the patient After arthrodesis patients are as a rule able to move freely the majority experienced no discomfort worth mentioning and were capable of performing heavy physical work

Though all methods used led to consolidation in the most cases the best results were quite clearly obtained by the Charnley method which usually produced consolidation within three months

The majority of complications and pseudarthroses occurred in cases where no internal fixation was used

Patients in general were satisfied with the results of their operations and the only cases to be regarded as bad are those in which infection made amputation necessary These were very few however in relation to the total number of arthrodeses

POST TRAUMATIC ARTHROSIS IN ANKLE AND FOOT TREATED WITH ARTHRODESIS by *Helge Fjermeros & Rolf Hagen* (Oslo Norway)

The basis for a development of secondary arthrosis is present if a fracture in ankle or foot has changed the anatomical and biomechanical relationships after union The most common causes are intra articular fracture lines with joint incongruity after reposition Another possible pathogenetic factor may be an increased strain upon the talonavicular and calcaneocuboid joints after a fracture of the calcaneus if the subtalar articulations are not accurately reduced anatomically

Oeparative Technique

The ankle joint is exposed through a posterior incision along the lateral or medial border of the Achilles tendon according to the correction of a varus or valgus deformity The articular cartilage is completely removed and the malleoli are osteotomised obliquely if necessary Bone chips are packed in the resection space and firm fixation is established by 2 staples An arthrodesis of the posterior subtalar joint can eventually be performed through the same incision By triple arthrodesis the involved joints are fixed with 3 staples

The patient is discharged 2 weeks postoperatively with a walking plaster cast Weightbearing is allowed after 2 months and usually the cast is removed 4 months postoperatively

The Series

During the period 19₅4–19C4 58 patients (62 feet) with post traumatic conditions were treated with arthrodesis 24 women and 34 men were re examined the average age by operation was 46 years and the average observation time 5 years The material consists of 3₅ malleolar fractures ₂1 calcaneus fractures and (fractures of the navicular bone The time period from the original trauma to arthrodesis was 1 years for the malleolar fractures but only 5 years for the calcaneus fractures

Follow Up Studies

Pseudarthrodesis definitely occurred in 3 patients (5 › per cent) Two of these patients have been reoperated upon with success 3 patients (14 3 per cent) with ankle fusion presented a subsequent arthrosis of the subtalar and tarsal joints unrelated to the original trauma which necessitated an arthrodesis Most of the

Pseudarthroses occurred in a total of 11 cases out of 60 i e in 18 per cent Table 1 shows the incidence of pseudarthroses in the fusion area correlated with the different methods of grafting autogenous bone The results clearly reveal the superiority of fresh transplants to the other transplant types The results obtained with homogenous bank bone used before 1960 are also shown Table 2 presents the correction obtained in the entire material Here too fresh bone grafts in vital condition appear to be clearly superior to autogenous bone transplanted in other ways Table 3 shows that clinically as well as roentgenologically good results were obtained in 44 cases out of 60 With fresh bone grafts good results prevailed in 30 out of 33 cases With bone grafts banked for two weeks results were good only in half the cases and a similarly fair result was obtained in the group whose transplants had been kept for 1 2 hours outside the organism The mean net correction was 17 degrees or 28 per cent

GUEST LECTURE

STANDARDIZATION OF SURGICAL IMPLANTS

by Mr *Norman Capener* (Great Britain)

Mr Norman Capener presented an outline of the work done by a committee of the British Standards Institution which has led to the development of a standard for the design of screws and plates used as surgical implants The work of this committee started in 1957 and the first standard was published in 1962 (B S 3531)

Careful consideration was given to the size and design of screws and to the related holes or slots in bone plates in order to provide optimum mechanical strength It was evident that there was a need for standardisation of the size of screws and the related holes or slots not only to ensure that correctly matching components were used but also to ensure the use of the correct size of twist drill and screw driver The mechanical problems provided by fractures of the major long bones of the lower extremity of adults have been shown to make desirable the use of screws of 4 mm nominal size The increase of the screw size from that commonly employed by surgeons namely 3 6 mm is very small compared with the added strength which is gained The nominal size of surgical screws (4 mm) has been designed in metric dimensions in accordance with current trends in British medical practice Further consideration is to be given to the specification of screws of smaller size for future revisions of the standard With the exception of the hole or slot in plates to receive the screws other details of design of surgical implants have been excluded from the scope of this specification

Metals for Surgical Implants

In the work of the British Standards Committee great assistance was provided by the metallurgists by screw designers by the experimental work of surgical instrument makers who all did much practical work in support of the committee s

Preoperative correction of all cases was carried out with the Milwaukee brace. Most of the patients were aged 13–15 years at operation. In all instances Cobb's method of spinal fusion was employed. In 10 cases bone grafts were taken from the tibia two weeks prior to the operation and stored in the bone bank. In 17 instances the tibial cortical bone and cancellous bone from the condyle was taken first and placed in a bowl whereupon the leg wound was closed. Then the spine was exposed and the fusion area prepared whereupon the grafts were put into place. In 33 cases the operation was carried out according to the current method of this clinic. To begin with the spinal bed was prepared. Then the cortical tibial bone grafts and cancellous bone from the condyle were taken and inserted immediately and in this way afresh. No post operative complications occurred. The mean follow up period was 2[illegible] months. At the final follow up examination most patients' spine had grown to their final size.

Table 2 Correction obtained following surgery
Idiopathic, paralytic and miscellaneous scoliosis

Type of fusion and of bone added	No. of cases	Average net correction Degrees	Per cent	No. of pseudarthroses
Cobb type fusion with banked autogenous tibial bone	10	13	18	3
Cobb type fusion with autogenous tibial bone kept in the open air 1–2 hours	17	10	14	7
Cobb type fusion with fresh autogenous tibial bone	33	16	28	1
Total	60			11

Table 3 Forty four cases with good treatment result correlated with the type of bone added

Type of bone added	No. of cases	Average net correction Degrees	Per cent
Banked autogenous tibial bone	5 out of 10	21	28
Autogenous tibial bone kept in the open air 1–2 hours	9 out of 17	15	22
Fresh autogenous tibial bone	30 out of 33	17	30
Total	44 out of 60	17	28
Bone bank bone treated before 1962	2[illegible] out of 96	15	2[illegible]

surgical screw Failure of a screw on insertion can be prevented by limiting the torque appl ed to the screw and a torque limiting screwdriver has been developed With this driver all screws may be tightened to the same degree

If the correct diameter of hole is drilled in bone and a screw having optimum mechanical properties is inserted using a torque limiting screw driver it is possible to prevent many failures of surgical screws

It was this work which guided the B S I committee in deciding upon the 4 mm crews as the most satisfactory one for use in the lower limb long bones of adults The ad antages of the self tapping screw were also clearly shown The disadvan tages of this however are in the difficulty of removal because of the growth of bone into the tapping flutes A difficulty which may result in excessive torque being applied with resultant breakage This work suggests that there is advantage to be gained by first tapping a screw thread in the drill hole Then the screw thread in the bone will be a cleaner one because there will be no blockage of flutes by the bone debri Under such conditions a non self tapping screw can be used and thus the greatest strength can be retained at the tip of the screw stem and of cource the screw can then be removed with less risk of breakage Such conclusions are of course supported by the work of Allgower and Muller in A O of Switzer land

Weakness in the use of any screw may develop by another type of defect in use This is the p ssage of a screw through two cortices of bone with equal threading of both Dr Scales has shown that the strength of a screw in one cortex is for practical purposes adequate There are mechanical advantages in having the thread upon the distal cortex Therefore surgeons should ream out the proximal cortex to a la ger drill size so that the screw will not cut a thread on it thus will be prevented the increased torsional stress that will be met when a screw passes be tween two threaded sections of material—the stress being due to the tendency of screw to force these two sections apart and thus increase the load As a result of a research arried out by screw manufacturers for us it was decided that 20 threads per inch should be the British Standard because it was shown that greater extracti n res stance i p ovided by the intervening sections of bone than with the close pattern of 3? thre ds per inch N tu ally one asks if an even greater size I s rew would h ve dv ntages Undoubtedl it would be so but there appears t be a risk that a larger d ill hole than that ad ised f r the 4 mm screw would pr vide a g eater risk of f acture of the bone at this point In any case according t Dr Scales w rk the crew of 4 mm di meter has more than adequate strength in most c r um tances of used pr perly

I will n t di uss t any length the question of the materials used The British Standards pecif ed three pos bles firstly an austenitic stainless stell of low car b n content the latter being n the neighbourhood of 0 08 per cent chromium 18–20 p r c nt n ck 1 8 10 per cent and molybdenum 2 3 5 per cent. The second material w s balt Ch ome/molybdenum alloy The third was titanium Stainless steel of the quality menti ned i n lmost ideal material but still has a slight tendency to pitting o crev ce rro i n How important this is I do not know in view of the g eate ri k in olve l in the mechanical def ciencies of technique which Dr Scale h s menti ned Cobalt-ch ome alloy has a disadvantage in its extreme hardness and d ffi ulty to work and the fact that it is a cast p oduct which has at any r te for sc ew some tendency t b ittl ness Titanium is lighter than these

studies There was however one piece of scientific work which I would particularly commend to you namely that of Dr John Scales of the Institute of Orthopaedics at the Royal National Orthopaedic Hospital in London Those of you who are familiar with the two articles which he and I wrote in the British Volume of the Journal of Bone and Joint Surgery in February 1965 will be aware of the general conclusions but will have less knowledge of the precision of his approach It is my intention to spend the greater part of the time available in outlining this which I do with his agreement and with his material It is a model of method which merits recognition and further application The conclusions arising from his work are as follows

Apart from dimensions the strength of the screw is dependant on the type of metal and the processes used in working the metal

It is possible with certain screwdrivers in use in operating theatres to apply a torque force of such magnitude as *to exceed the torsional yield stress and to break* any surgical screw having a core diameter of less than 0 120 The influence of core size and tensile strength of the metal on the torsional yield stress of screws having a nominal external diameter of 9/64" (3 6 mm) and 5/32 (4 mm) has been investigated

Of the five groups of screws tested the most suitable was that having an external diameter of 4 mm (5/32) and a core size of 0 119" The average Vickers Pyramid diamond hardness number of the screws indicated that the wire from which the screws were made had a tensile strength of approximately 78 ton/sq inch Tensile tests of the wire carried out by the manufacturers showed that its actual tensile strength was 70 5–73 5 tons/sq inch The mean torsional yield stress of the screws was 47 lb inch with a minimum value of 43 lb inch When the group 9/64 screws are compared with the group 4 mm (5/32") screws it is found that 13 per cent (0 014") increase in the core diameter gives a 44 per cent increase in the mean torsional yield stress

In the lower limb of an adult a screw may be highly stressed and thus a screw with the best mechanical properties is required Experiments with human bone using self tapping and non self tapping screws have shown that less torque is developed during the insertion of the self tapping screws

There is a great variation in mechanical properties of human bones The maximum extraction force to pull out a self tapping 4 mm (5/32") screw inserted in one cortex of the human femur was 0 720 tons or 1612 lbs while the minimum extraction force with the same type of screw inserted in another bone was 0 110 or 246 lbs Both screws were inserted in holes drilled with a 0 125 drill The use of intermittent or continuous rotation is an important factor affecting torque developed during insertion of a screw If a non self tapping screw is inserted by intermittent rotation into both cortices of a bone and a clearance hole is not drilled in the proximal cortex then the torque developed may exceed the torsional yield stress of the screw The growth of bone into the flutes of a self tapping screw is said to be responsible for the breaking of screws when they are removed Perhaps the failure are initiated during the insertion of the screw?

An 0 125" drill is the most suitable size to use with a 4 mm (5/32") screw having a nominal core diameter of 0 118" If the bone is exceptionally hard then a drill of 0 1285" can be used

There are a number of factors which can bring about or initiate the failure of a

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From the Surgical Research Laboratories College of Medical Sciences
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FRACTURE HEALING WITH INTRA MEDULLARY NAIL FIXATION OF THE LONG BONES

An Experimental Study

By

B P VARMA & S H MEHTA

Received 9 IX 66

Intramedullary nails are becoming increasingly popular in the management of fractures of long bones The effect of the nail on the process of fracture healing is a controversial but fundamental issue *Kuntscher* (8) himself stated that the nail stimulates callus formation and speeds the healing process whereas *Boehler* s (2) conclusion was that the nail often inhibits callus formation Clinical experience through the years has shown that following intramedullary nailing delayed union is the rule and one does come across cases of non union even Since *Murray* (10) advocated immediate internal fixation doubt has been expressed about its utility by various workers *Smith* (12) reviewing fractures of radius and ulna fixed internally suggested delayed internal fixation which in his view *permitted the local* circulation to re establish itself He also found that the incidence of non union was *reduced by delaying* the operation until 1–3 weeks *Charnley* (3) *James* (7) *and Smith* (13) have also reported about the better results of delayed Kuntscher s nail fixation for fractures of the femoral shaft *Gothman* (5) working on rabbits noted that there was greatest vascular *response if* fractures of the tibia were treated by intramedullary nail 2–4 weeks after the injury On the other hand *Warren Fraser* (16) and *Harman Smith* (6) did not think that late nailing was in any way beneficial

On the basis of these *observations* the present work has been under taken on rabbits to study the *fracture* healing process in the presence of the intramedullary nail and also *to study* the effect of nailing at different intervals after the injury on the process of fracture repair

other alloys is a pure metal and in certain situations has real advantages I will not discuss this further

The corrosion resistance of austenitic steel has been improved recently by raising the chrome and nickel content A small revision of the British Standard material for steel is now being published but its use will still be compatible with the existing standard material

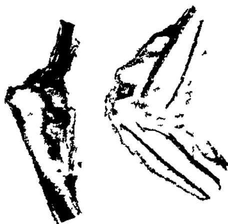


Figure 1 Wh le se tion p! t graph of control sp imens left 4 weeks and right six week after fra ture shou u g thick external callus

weeks Sound clinical union had occurred at four weeks with marked over riding and angulation (Figure 1) Microscopically at four weeks the callus comprised mainly immature bone trabeculae with a thin zone of cartilage at the centre which was being invaded by new bone from both ends the so-called endochondral bone formation The periosteal new bone formation at a site away from the fracture line occurred



Figure 2 Phot micrograph of six weeks ontr l spe imen shou in a one of cartilage in the c ntre bei g invaded by new bone f om both the ends × 41.9

MATERIAL AND METHODS

17 rabbits each weighing about 1¹ 1gms were selected *for the experiments* The animals were divided into 4 groups as shown in Table 1

Table 1

Group	Procedure	Animals sacrificed			Total
		2 weeks	4 weeks	6 weeks	
Control	Closed fracture tibia No fixation	Nil	1	2	3
Group I	Closed fracture tibia with immediate i m nailing	1	2	3	(
Group II	Closed fracture tibia with i m nailing after one week of fracture	1	1	4	(
Group III	Closed fracture tibia with i m nailing after two week of fracture	Nil	1	1	›
					17

Closed fracture of the tibia was produced under inhalation anaesthesia with ether and the procedures as mentioned in the Table 1 were carried out Kirschner s wire was used for intramedullary fixation which was passed through a drill hole on the medial surface of the upper end of the tibia after exposing the fracture site Up to the time of killing the animals were given normal food and unlimited water Post operatively Dicrysticin was given for three days to each animal Total period of experiment in each animals were sacrificed after two weeks four weeks and six weeks from the time of the fracture Serial radiographs were taken at intervals of two weeks *at two weeks four weeks* and six weeks up to the time of sacrifice and the amount of radiological callus was noted On sacrifice the affected bone was dis sected and a macroscopic study was made with respect to the amount of thickening and evidence of clinical union *after* extracting the nail A photographic record of each bone was kept

A histological study of each specimen was carried out The sections were stained with haematoxylin and eosin and also with Hale s colloidal iron stain as modified by *Rinehart and Abul Haj* (*Lupa & Prasad* (14)

RESULTS

In the control group *three animals were studied All the three fractures* healed with overlap and gross angulation In the four weeks specimen there was good radiological callus which had fully consolidated at six



Figure 3 Whole section photograph of 2 weeks specimens left after immediate nailing and right nailing done after one week of fracture showing a much thicker periosteal callus in the latter

other at 6 weeks in group II and the third also at 6 weeks from the time of fracture in group III Out of 7 unstable fixations 3 united all the three from group II where intramedullary nailing was done after one week of the fracture

Table 4 An analysis of result of Group III

Weeks	Animals studied	Stable fixation	No of unions
4	One	Nil	Nil
6	One	One	One
Total			One

TWO WEEKS SPECIMENS

Two animals were sacrificed at two weeks from the time of fracture—one in group I and the other in group II In both the fixation was unstable Skiagram revealed periosteal callus in both Local thickening was much more marked in group II Microscopic examination showed periosteal callus comprising collagen cartilage and immature new bone which was much more abundant in group II bridging across the fracture site (Figures 3 and 4)

mainly by direct transformation of collagen into new bone There was evidence of endosteal new bone formation as well and the medullary cavity was plugged with callus The main mass of new bone between the displaced fracture ends seemed to form by the organisation of fracture hematoma In the six weeks specimens more or less the same microscopic picture was seen with a zone of cartilage still persisting at the centre (Figure 2)

Table 2 An analysis of result of Group I

Weeks	Animals studied	Stable fixation	No of unions
2	1	Nil	Nil
4	2	One ——→	One
6	3	One	Nil
			(Two specimens with unstable fixation showed low grade infection)
Total	6		One

Table 3 An analysis of result of Group II

Weeks	Animals studied	Stable fixation	No of union
2	1	Nil	Nil
4	1	Nil	One
6	4	2	3
			Stable 1 Unstable 2
Total	6		4

Of the remaining 14 animals in whom the fractures were fixed by intramedullary nail some amount of lateral mobility was possible after fixation in nine animals whereas in five animals the fixation was relatively stable at surgery because of the nail penetrating well within the lower end of the tibia Results are presented in Tables 2 3 and 4

Out of 12 fractures studied for 4–6 weeks in all the nailed groups 6 united—one in group I four in group II and one in group III Out of 5 stable fixations 3 united -one at the end of 4 weeks in group I an



Figure 6 Skiag am sh wing primary unin u ith minimum of peripheral callus four ueeks after immediate nailing stable fixation

FOUR WEEKS SPECIMENS

Four animals were sacrificed at 4 weeks from the time of fracture—two in group I and one each in group II and III respectively One specimen in group I had a stable fixation and the other three were unstable at



Figure 7 Photom crograph of f ur u eeks spe imen after immediate na ling referred to in Figu es 5 an l 6 shou ing a g o l new bone formation without any ca tilag e ll × 41 9



Figure 4 Photomicrograph of two weeks specimen after delayed nailing (one week) showing excess of cartilage cells with new bone formation × 41 9



Figure 5 Skiagram showing stable fixation with good callus two weeks after immediate nailing

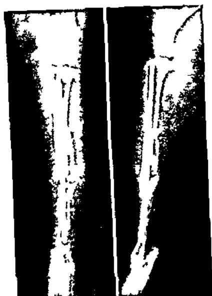


Figure 10 Skiagram six weeks after delayed nailing (one week) showing a good periosteal callus with a transverse cleft in the callus at the fracture site Stable fixation

peripheral callus comprising well formed trabeculae with a small zone of cartilage still persisting (Figure 8)

The group III specimen showed slight mobility at the fracture site On microscopic examination there was a thick periosteal callus bridging across the fracture site with large islets of cartilage collagen and new bone (Figures 8 and 9)

SIX WEEKS SPECIMENS

Eight animals were sacrificed after six weeks from the time of fracture 3 in group I 4 in group II and one in group III Of these 8 fractures 4 had stable fixation at surgery—one in group I two in group II and one in group III

In group I none of the three specimens showed clinical or radiological union Skiagram showed extensive preiosteal reaction involving the whole shaft along with early sequestration of the shaft of the upper fragment in two animals There was no evidence of infection externally Both these animals showed scanty callus comprising new bone cartilage and collagen Probably both of these had suffered lowgrade infection



Figure 8 Whole section photograph of four weeks specimen left immediate nailing centre delayed nailing (1 week) and right delayed nailing (2 weeks) showing a thicker callus in the delayed nailing group both of which had loose nail fixation

surgery The one with a stable fixation in group I united at 4 weeks with a minimum of peripheral callus and microscopically new bone was seen without any zone of cartilage anywhere (Figures 5 6 and 7) The other specimen in this group with unstable fixation did not unite and showed poor callus comprising new bone and cartilage

The group II specimen at 4 weeks showed clinical union with a thick



Figure 9 Photomicrograph of four weeks specimen after delayed nailing (2 weeks) showing new bone formation with collagen and a large area of cartilage cells unstable fixation × 41 9

fracture ends seemed to form by the organisation of fracture hematoma followed by endochondral new bone formation. A thin zone of cartilage invaded by new bone from both ends persisted at the centre till 6 weeks. The periosteal new bone formation at a site away from the fracture line was mainly by direct transformation of collagen into new bone—intra membranous new bone formation.

As compared to the control series where all the three fractures healed in 4-6 weeks time, in the nailed series only 6 fractures out of 12 healed in the same period (50 per cent). This is quite consistent with the clinical impression that union is delayed following operative reduction and internal fixation as compared to the fractures treated without surgery under optimum conditions for healing of the fracture.

Among the nailed fractures, union has been better among those which had stable fixation at surgery, 3 out of 5 uniting in 4-6 weeks. The healing in these fractures has occurred by direct transformation of collagen into new bone with a minimum of peripheral callus and as early as 4 weeks after fracture in group I animal where the overall result was poor. In contrast to this, with loose unstable fixation only three out of seven united and in these cases healing took place by a greater amount of peripheral callus with endochondral new bone formation. Of the two fractures in the stable group which did not unite, one belonging to group II studied for six weeks showed a good callus with a *cleft* in it at the fracture site because of which mobility was possible. Probably due to subsequent loosening of the nail after surgery mobility occurred at the fracture site which produced this cleft or fracture of the callus. The *other one* in the stable group which did not unite belonged to group I studied for 6 weeks. Here the fragments were quite sticky though not fully united and possibly this would have healed if given time. In this very *group I* the one at four weeks with a stable fixation had healed with a good primary union. There is also a possibility that the fixation in the former was not as stable as in the latter. Hence it seems that the *main factor* which seems to influence the result in the nailed fracture is the stability of fixation. With a stable fixation healing occurs early by a direct intramembranous new bone formation with little peripheral callus, whereas *with* loose fixation there is a greater amount of periosteal callus formed by endochondral new bone formation. Almost the same *type of healing* as in loose fixations occurred in the control group without any immobilisation where the callus was much more abundant with plenty of cartilage in it persisting for six weeks. Therefore the main factor which favours chondrogenesis in

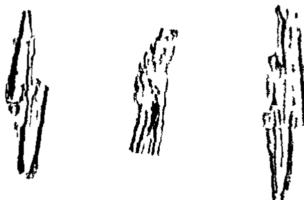


Figure 11 Whole section photograph of six weeks specimen left immediate nailing centre delayed nailing (1 week) and right delayed nailing (2 weeks) showing primary healing in the delayed nailing group — All stable fixation

which had not produced external signs The third specimen which had a stable fixation showed no peripheral callus radiologically and the fracture line was faintly visible The fragments were sticky clinically, but not fully united On microscopic examination scanty new bone was seen without any cartilage

In group II, three out of four specimens showed clinical and radiological union of which one had a stable fixation and two had unstable fixation at surgery The fourth specimen was a stable fixation in this group showed slight mobility at the fracture site The skiagram of this specimen showed a good periosteal callus with a transverse cleft in the callus at the fracture site (Figure 10) The specimens with unstable fixation showed thick peripheral callus consisting of collagen cartilage and new bone whereas the one with stable fixation showed relatively less of peripheral callus comprising new bone and collagen without any cartilage (Figure 11)

In group III the only specimen showed a primary union with little peripheral callus consisting of new bone (Figure 11) No cartilage was seen This was again a stable fixation

DISCUSSION

In the control group studied without any immobilisation all the three fractures healed in 4–6 weeks from the time of fracture with overlap and angulation The main mass of new bone between the displaced

All the three control fractures studied without any immobilisation healed in four to six weeks time with overlap and gross angulation by a thick callus comprising new bone and cartilage Cartilage cells persisted even till six weeks after the fracture

Among the nailed fractures the result was better with stable fixation which produced a primary healing with a minimal of external callus by direct transformation of collagen into new bone With loose fixation there was a greater amount of external callus and the healing took place by endochondral new bone formation

Among the loose fixations the results were uniformly poor in group I fractures where nailing was done immediately whereas in group II fractures treated by I M nailing after one week of the fracture all the three fractures had healed in four to six weeks with a thick *peripheral* callu There wa evidence that delayed nailing accelerated the fracture repair process by a generalised acceleration in the proliferation of fibroblasts chondroblasts and osteoblasts

RESUME

La guerison de fracture par clouage intramedullaire a ete etudiee sur 17 fractures de tibia de lapins par les methodes de la *macroscopie* radiologie et histologie

Toutes les trois fractures de controle etudiees se guerirent sans immobilisation dans l'espace de quatre a six semaines avec *recouvrement* et grosse angulation par un epais cal *comprenant nouveau tissu osseux* et cartilage Les cellules cartilagineuses ont *persiste jusqu'a* six semaines apres la fracture Parmi les fractures enclouees le resultat a ete meilleur lorsque la fixation a *eté stable* Elle a produit *was guerison* primaire avec un *minimum de cal* externa par transformation directe *de* collagene en nouveau tissu osseux Lorsque la *fixation* a ete moins *stable* il y a eu une plus grande quantite *de* cal externe et la *guérison* s'est faite par formation enchondrale de *nouveau tissu osseux*

Dans les cas de fixation *moins stable* les resultats ont ete *uniformement* piètres dans le *groupe I* ou l'enclouage a eu lieu *immediatement* alors que dans le *groupe II* des fractures traitees par enclouage intramedullaire l'enclouage a ete *pratique* une semaine apres la fracture Toutes les trois fractures se *sont gueries* dans l'espace de quatre a six semaines avec un épais cal *peripherique* Il est apparu avec evidence qu'en differant l'enclounage on *active* le processus de restauration de la

the fracture repair process is the mobility at the fracture site the greater the mobility the more the amount of cartilage formation Recent work by *Bassett* (1) on tissue culture has shown that primitive mesenchymal cells exposed to high oxygen concentration and compression developed into osteoblasts low oxygen tension and compression produced chondroblasts whereas tension or distraction produced fibroblasts Perhaps mobility is responsible for prolonged avascularity at the fracture site by hampering the in growth of capillaries which does not take place till the mobility is reduced by the formation of the primary fibrocartilagenous callus favoured due to low oxygen tension caused by relative ischaemia When the fracture is rigidly immobilised by internal fixation the in growth of capillaries can take place more rapidly and hence there is direct new bone formation

Again amongst the loose fixation all the three fractures that healed belonged to group II where the nailing was delayed for one week one united at four weeks and the other two at six weeks Moreover the callus formation in this group as well as in the group III four weeks specimen was much more abundant as compared to group I where nailing was performed immediately Even the two weeks specimen in group II showed much more marked cellular proliferation as shown by a large spindle shaped periosteal callus with plenty of cartilage collagen and immature new bone as compared to the group I specimen Hence one may possibly conclude though not very firmly on the basis of these small series of experiments that delayed nailing accelerates the fracture repair process by a generalised acceleration in the proliferation of fibroblasts chondroblasts and osteoblasts When intramedullary nailing of a closed fracture is delayed for one to two weeks the operative procedure in fact inflicts a second trauma during the healing phase of the original fracture which might accelerate the proliferation of reparative cells In the case of soft tissue wounds the fact that secondary wounds heal faster than primary wounds has been clearly established both by clinical impression in human beings and by actual measurements in laboratory animals *Erk I Peacock* (4) The same phenomenon might be responsible for better healing following delayed nailing

SUMMARY

Fracture healing with intramedullary nail fixation has been studied on 17 fractures of the rabbit's tibia by macroscopic radiological and histological methods

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6 Harman Smith (196) *J Bone Jt Surg* 47 B 600

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8 Kuntscher Quoted by William T Fitts Jr et al

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fracture par l'accéleration générale de la proliferation des fibroblastes des chondroblastes et des osteoblastes

ZUSAMMENFASSUNG

Knochenbruchheilung bei intramedullärer Nagelung wurde an 17 Tibiabrüchen von Kaninchen mittels mikroskopischer röntgenologischer und histologischer Methoden studiert

Alle drei Kontrollbrüche die ohne Ruhigstellung studiert wurden heilten innerhalb von vier bis sechs Wochen mit Überschiebung und schwerer Winkelung mittels eines dicken Kallus der neuen Knochen und Knorpel enthielt Knorpelzellen bestanden selbst noch bis zu 6 Wochen nach dem Bruche Bei den genagelten Brüchen war das Ergebnis besser mit einer stabilen Fixierung die eine primäre Heilung mit geringem externem Kallus mittels direkter Umformung von Kollagen in neuen Knochen hervorbrachte Bei loser Fixierung war eine grössere Menge von externem Kallus zu sehen und die Heilung geschah mittels enchondraler Bildung von neuen Knochen

Bei den losen Fixierungen waren die Ergebnisse durchgehend schlecht in der Gruppe I in der die Nagelung unmittelbar nach dem Bruche vorgenommen wurde während in der Gruppe II in der die Nagelung eine Woche nach den Bruche ausgeführt wurde alle drei Brüche nach vier bis sechs Wochen mit einem dicken peripheren Kallus ausgeheilt waren Es war augenscheinlich dass die verzögerte Nagelung den Bruchheilungsprozess wegen einer allgemeinen Proliferationsbeschleunigung der Fibroblasten Chondroblasten und Osteoblasten beschleunigte

ACKNOWLEDGEMENT

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MUSCLE FUNCTION IN KNEE EXTENSION

An EMG Study

By

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Received 12.X.66

In clinical orthopaedic work one often encounters problems concerning the function and exercise of the quadriceps. After trauma in the knee region, including surgical trauma, it is important that the function of this muscle should be recovered rapidly and completely. During its exercise there is not infrequently a residual active extension defect in the knee joint, although there is no interference with full passive extension. Even after properly planned and executed exercise of the quadriceps and maximum effort, the patient is unable to perform the last 10–15 of the extension. In the present study the part played by the various portions of quadriceps during extension was examined by electromyography under normal and pathologic conditions. The study is a continuation of a series on the function and mobility of the knee joint (4–8).

MATERIAL AND METHODS[1]

A six channel EMG apparatus was used (Grass Polygraph model). Synchronous recordings were obtained with surface or needle electrodes from the vastus lateralis, rectus femoris and vastus medialis muscles. They were performed during maximum isometric contractions of the quadriceps in the recumbent and seated positions and with the knee joint in different positions between 90 and extension—that is, the position where a firm resistance is encountered, whether at 180, 185 or 190.

Fifteen normal subjects were examined in this way. Special attention was given to the following points: (1) Whether there was any difference in the activity from the three muscles, (2) whether there was any interval between the onset of activity in the different portions of the quadriceps muscle, and (3) the difference in these

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1 The study was planned in consultation with L. E. Larsson, M.D., former head of the Department of Neurophysiology, Umeå.

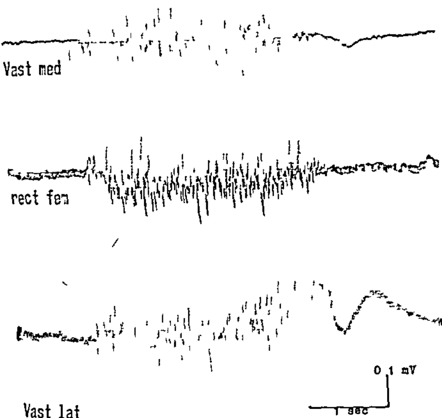


Figure 1 4 EMG w th simultaneous r cording from different p) tions of the quadri c ps n u cle (s irf ce el ctr d s) Healthy man aged 19 years Recumbent uith knee flex d 90 I ot erful a tivity was obtained

tw) re pects for ar ous angles f the knee joint in the eated and recumbent positi n

The xamin tion w s lso performed on 8 patients that had recent v un lergone knee perati ns and h prol al ly owing to pain had not been able to raise the leg fr m th h rizontal an l on 7 patients wh had (lde lesions n or near the knee J int A few month after the lesion the e still had an active extension defect of al ut 10 in the kn e joint Fin lly examinat ons were performed n 4 subjects in wh m th va tus m li li ha l been blocked n lo with a l l anae th tic (C ta ne t 0 5 per cnt 0 80 ml) EMG rec ding were made at interva s of about 5 minute bef re nd after blocking and with surface electr le in pl ce

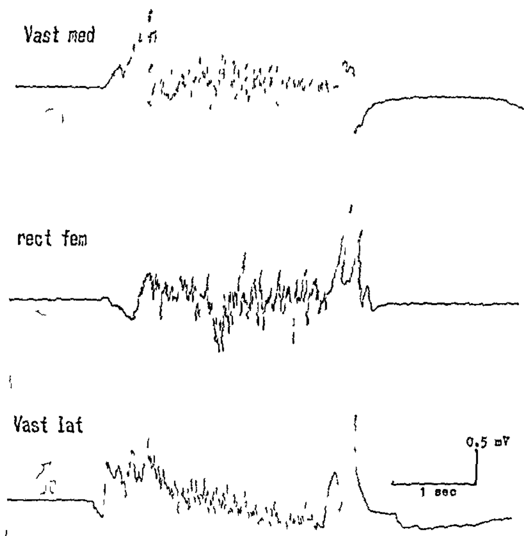


Figure 1 B. EMG with intramuscular needle electrodes. Healthy man aged 32 years. Recumbent with knee extended.

RESULTS

Where surface electrodes were used in normal subjects certain individual differences in the readings were found, as expected. Young lean persons with powerfully developed muscles recorded higher activity (Figures 1 A and B). In older persons with thick subcutaneous fat and less well developed muscles the values were often lower (Figure 2).

As regards the three points specially mentioned above, no difference in the activity from the three muscles could be demonstrated, nor was there any clear difference as to the onset of the activity between the various portions of the muscles, with reservation for the possibility that

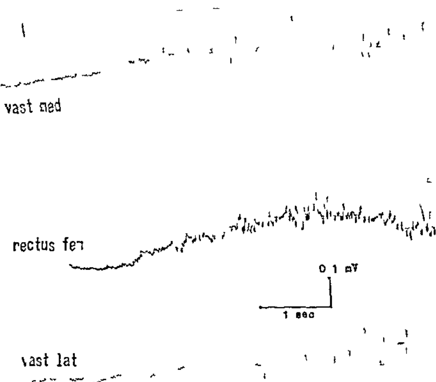
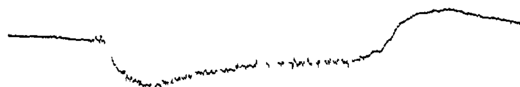


Figure 2. Healthy woman of 60 years with moderate subcutaneous fat. Recumbent with knee at 135°. Generally less activity than in Figure 1 (surface electrodes).

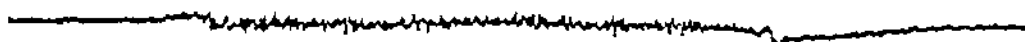
very small time differences could be masked by motion artefacts. As regards the third point there was no difference in activity between the portions during the various phases of extension. The same activity of the vastus medialis was found for both 90 and 135° in the recumbent and seated positions as in extension. These findings were in agreement with those of *Close* (2).

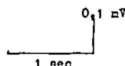
The 8 patients that had recently undergone operations and that were unable to raise the extended leg owing to pain inhibition recorded extremely irregular and weak activity from all the muscles tested (Figures 3 A and B). No differences in respect of the above three points were found.

Vast med



rect fem





Vast lat

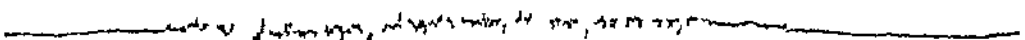


Figure 3 A Man aged 47 years 2 days after meniscectomy in the tested knee joint Could not raise the leg from the horizontal Recumbent with knee extended Weak irregular activity (surface electrodes)

In the group of patients with older knee injuries and residual active extension defect it was of course impossible to measure the muscle activity in extension but in the other positions there was no difference in the action potentials from the 3 muscles as regards time or other properties and in maximal extension for the individual case the activities were identical (Figure 4)

In the subjects in which the muscle activity was examined before and after infiltration of the vastus medialis with a local anaesthetic there was a clear reduction in the activity in the anaesthetized vastus medialis (Figures 5 and 6) It should be noted in this connection that the patient himself did not feel any appreciable difference in the power of exten

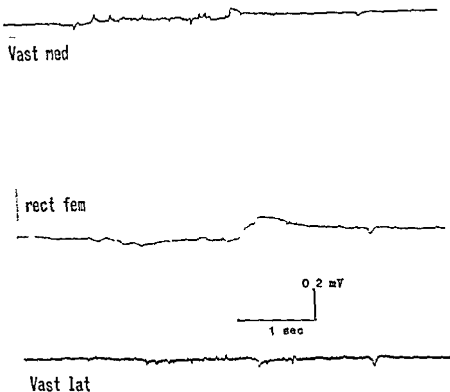


Figure 3 B FMG with intramuscular needle electrodes Woman aged 16 years 2 days after op rati n in the teste l knee joint Coul l not raise the le j from the hori ontal Re umbant with knee exten led Weak irregular activity

sion and that the knee could still be extended fully and to the same position as before infiltration In one case in which an attempt was made to block the branches of the femoral nerve higher up where they entered the vastus medialis no definite reduction in activity was recorded although quite large volumes of anaesthetic were injected

DISCUSSION

One object of this study of quadriceps function was to examine the causes of residual active extension defect in the knee joint a familiar

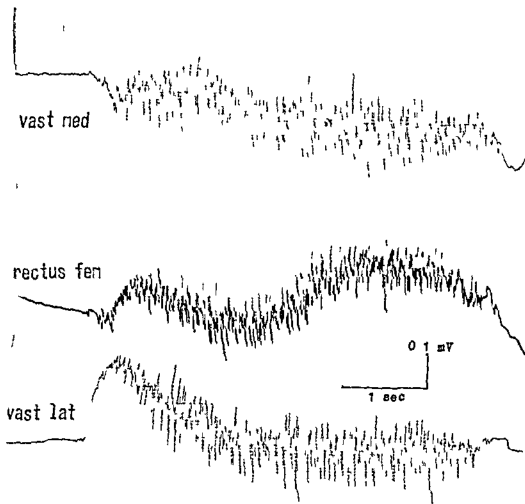


Figure 4 Man aged 56 years 6 months after fracture of the femur 10 active extension defect in the knee Recumbent with the knee at 170 No difference in activity for the 3 portions of the muscle (surface electrodes)

condition that has been dealt with thoroughly by *De Palma* (3) In common with this author *Smillie* (9) ascribes exceptionally great significance to the vastus medialis in the terminal extension of the knee These workers base their views on the clinical observations that the belly of the vastus medialis is most prominent in full extension and that of all the portions of the quadriceps it is the one that is most severely atrophied after injury and is then the most difficult to exercise *Smillie* closes his article with the statement Vastus medialis is the key to the knee The importance of this muscle is also stressed in the training of physiotherapists in Sweden (1)

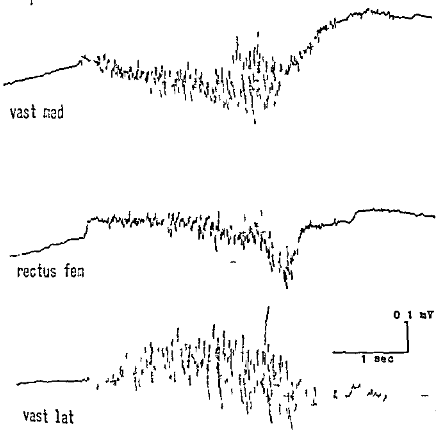


Figure 5 Healthy man aged [illegible]0 years Recumbent with knee at 135° Normal activity (surface electrodes)

The view that the vastus medialis functions only during the last 10–15° of extension and then assumes practically sole responsibility for the extension would seem *a priori* to be of doubtful validity if the quadriceps muscle is regarded as a unit consisting of four portions all of which converge and are attached to the patella the force then being transmitted to the tibia *via* the ligamentum patellae That the muscle is most easily palpated and most prominent when the knee is fully extended is probably due to the fact that it is thickest when fully shortened this would apply also to the other portions of the quadriceps which however are not so visible This phenomenon can also be seen in normal subjects when with a flexion of 10–15° the vastus medialis

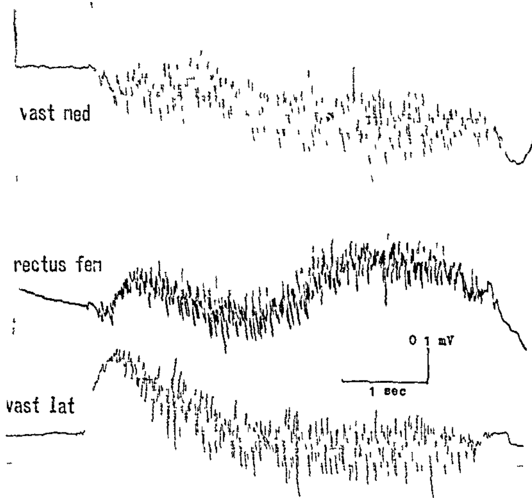


Figure 4. Man aged 16 years, 6 months after fracture of the femur. 10° active extension defect in the knee. Recumbent with the knee at 170°. No difference in activity for the 3 portions of the muscle (surface electrodes).

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The activity recorded from the vastus medialis was normal even for the patients with residual active extension defect. Elimination of the vastus medialis by infiltration with Citanest (Figure 6) did not prevent full extension of the knee joint.

If then the vastus medialis has no special function in the terminal extension of the knee joint, how is the residual active extension defect to be explained? There would seem to be four factors that suffice to account for the phenomenon:

1) In the actual terminal extension the lever action of the quadriceps is diminished (*Lindahl & Movin* (8)).
2) According to von Schwann's law a muscle exerts its greatest force when it is fully extended (though not overstretched), the force decreasing as maximum shortening is approached.
3) Inhibition of pain, especially in acute cases.
4) Parapatellar shrinkage of the joint capsula and adhesions between the quadriceps and femur.

SUMMARY

The muscular activity in the quadriceps was studied electromyographically under normal conditions as well as in cases of the residual active extension defect in the knee joint often seen after traumatic knee lesions. In contradiction to the general opinion it was found that the vastus medialis did not assume any specific function in the terminal extension of the knee. The extension defects may be ascribed to the following four factors:

1) The quadriceps exerts the poorest leverage in the last 10° of extension.
2) In accordance with physiological laws the muscular power decreases as the muscle *shortens*.
3) Pain inhibition.
4) Adhesions.

RÉSUMÉ

L'activité musculaire du quadriceps a été étudiée *par électromyographie* dans des conditions normales comme dans des cas de déficience résiduelle d'extension active de l'articulation du genou que l'on constate souvent après les lésions traumatiques *du genou*. En contradiction avec l'opinion générale on a constaté que le vastus medialis n'assume pas

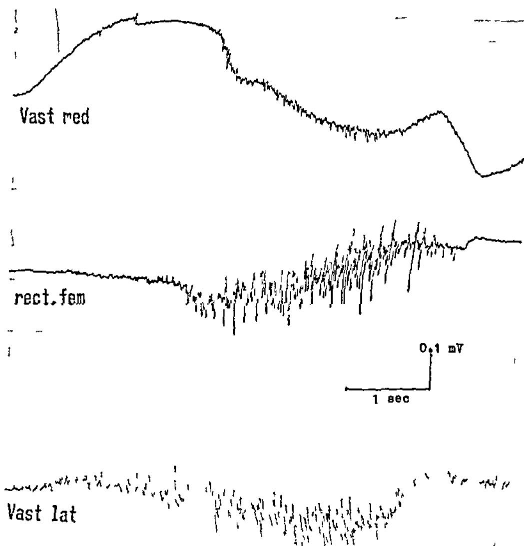


Figure 6 The same conditions as in Figure Twenty millilitres of local anaesthetic were injected into the vastus medialis with the surface electrodes in place Full active extension in the knee joint There was a clear reduction of the activity of the anaesthetized muscle

is poorly outlined in spite of maximum tension Only in full extension and powerful contraction which after operation or other trauma often give rise to pain and are avoided is the peripheral belly of the vastus medialis clearly seen and normal in appearance

This EMG study thus provides no support for the view that in extension of the knee the vastus medialis differs from the other parts of the quadriceps muscle in both the normal subjects and the patients the vastus medialis reacted throughout extension just as the other portions

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Banaras Hindu University Varanasi-5 (India)

TUBERCULOSIS OF SPINE

By

S M Tuli T P Srivastava B P Varma & C P Sinha

Received 27 X 6[illegible]

Skeletal tuberculosis is one of the disappearing problems of the advanced countries in the West They have been able to achieve it because of universal pasturization of milk eradication of pulmonary glandular and visceral tuberculosis and segregation of open cases in sanitorium All these facilities do not exist in India and presumably in other economically under developed countries of the world Tuberculosis of bones and joints still remains one of the major problems to any Orthopaedic service in our country Spinal caries is the most common and is the most dangerous form of skeletal tuberculosis Caries spine constitutes about [illegible]0 per cent of all cases of skeletal tuberculosis in any series

MATERIAL

The present paper is based upon the observations made on 270 cases of tuberculosis of spine who attended the Orthopaedic service of the College of Medicine Sciences Banaras Hindu University between February 19[illegible]5 to February 1966 Table 1 shows the incidence of skeletal tuberculosis and that of spinal caries in our series during this period of one year

Table 1 Showing Incidence of Skeletal Tuberculosis and that of Spinal Caries

Patients attending Orthopaedic Out *Patient Department*	80[illegible]0
Patients with skeletal tuberculosis	580 (7 [illegible]% of all Orth cases)
Patients with spinal tuberculosis (excluding sacroiliac and sacrum)	270

une fonction spécifique dans l'extension terminale du genou. L'extension défectueuse peut être attribuée aux quatre facteurs suivants:

1) Le quadriceps fournit le moment le plus faible dans les derniers 10° de l'extension.
2) Conformément aux lois physiologiques la force musculaire diminue lorsque le muscle est raccourci.
3) Inhibition par suite de douleurs.
4) Adhésions.

ZUSAMMENFASSUNG

Die muskuläre Aktivität des M. quadriceps wurde unter normalen Verhältnissen und in Fällen von zurückbleibendem aktivem Streckdefekt des Kniegelenkes, der oft nach traumatischer Beschädigung des Knies gesehen wird, elektromyographisch untersucht. Im Gegensatz zur allgemeinen Auffassung wurde gefunden, dass der Vastus medialis keine besondere Funktion bei der Endstreckung des Knies übernimmt. Der Streckdefekt kann auf die folgenden vier Faktoren zurückgeführt werden:

1) Der Quadriceps übt die geringste Hebelwirkung während der letzten 10° der Streckung aus.
2) In Übereinstimmung mit physiologischen Gesetzen nimmt die Muskelkraft mit der Verkürzung des Muskels ab.
3) Schmerzhemmung.
4) Adhäsionen.

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sacral junction There were 25 patients (9 ? per cent) who had involvement of more than one region of the spine each region being separated by two or three normal vertebrae For Table 4 they have been included under the region which had the more advanced lesion Friedman (1966) described 84 spinal lesions in 64 of his patients of tuberculosis of spine Our figures give a rather higher incidence for involvement of cervical spine It is suggested that this may be explained on the basis of the large number of children suffering from spinal tuberculosis in our series cervical spine tuberculosis being more common in children

Table 4 Distribution of Tuberculosis in Spine

Sites of lesion	Number	Percentage
Cervical	38	14 0
Dorsal	118	43 7
Lumbar	106	39 3
Lumbo sacral L –S_1	8	3 0

NB 25 cases (9 ? per cent) had isolated lesion in more than one region of spine

R lation betwe n spinal lesion and other visceral and skeletal lesions Like o teo art ular tub rculosi spinal tube cu o is is always the result of a haematogenous dissemination from a primary focus The pr mary focus may be act ve or quies ent apparent or latent either in the lungs or l mph glands of mediastinum mesentry or neck r there may be invol ement of other vis era The detection of the primary focu or n as ociated visceral lesion greatl depends upon the degree of effort put in this direction In the present series a pulmonary lesion could be detected in five per cent of the cases and cervical lymphadenitis in seven per cent of the cases The dete t on of as ociated vis eral lesions in the series of other workers (*Konstam* 196? *Fri d nan* 1966 *Wilkinson* 1949 and *Sanchis Olmos* 1948) has been reported to be rather high between 40 and 50 per cent 56 out of ?70 patients with spinal *tuberculosi* (?1 per ce it) had disseminated skeletal lesions either as multiple fo i in i l ted r gion of th sp ne o with in ol ement in other regions of the skeleton T l le 5) Ten out of 64 patients with spinal tuberculosis in *Friedman* s series (196) had tuber ulou osteomyel ti of other bones in addition to the ve tebral focus

I rt b al les on In the majority of the patients there were the typical parad scal l i ns h a teri ed by destruction of the adj cent bone and end plates of the b li s nd the intervening *interve tebral* dis The fol owing uncommon varieties al o nc unter d whi h ma how radiol gically int ct dis spaces These were the nt io type in two *ca es* (*inv lvement* of anter o surface only) (Figure1) I t ri pinal d s se In on (invol ement of pe li les laminae or spinous pro c) n l the centr l cystic type of tuberculosi of bod of the ertebrae in two c

Abs ss and S nu es Tuberculous abs e ses were diagno ed on the basis of the char ct ti roentgen graphic e dence or detection of pus on aspiration or evac tion an l lini al ex mi t *on* of palpable abs ess There were 103 cases (*i e*

Age and Sex What is true of osteoarticular tuberculosis in general is also true of spinal tuberculosis It is most common during first three decades Table 2 shows the age distribution Out of a total of 270 patients 124 were males and 146 were females The figures of other workers are almost similar (*Konstam* 1962 *Friedman* 1966 *Wilkinson* 1949)

Table 2 Age Distribution (at the Time of Onset of the Disease) Amongst Spinal Tuberculosis Patients

Age	Number	Percentage
Below 11	85	31.5
11 – 20	74	27.4
21 – 30	67	24.8
31 – 40	17	6.3
41 – 50	14	5.2
51 – 60	7	2.6
61 – 70	4	1.5
Above 70	1	0.4

CLINICAL AND RADIOLOGICAL FEATURES

The majority of the patients reach the hospital late when the disease is *fairly advanced* The duration of symptoms of the illness at the time of presentation in the hospital in the present series is given in Table 3 The duration varied between a few months to a few years Less than 20 per cent of patients attended within first three months of the onset of the symptoms The delay may be due to socioeconomic factors and due to ignorance regarding the gravity of their ailments A large number of patients seek advice only when there is severe pain marked deformity or when the patient has developed neurological complications Ninety four per cent of the patients in the present series had varying degree of kyphosis at the time of presentation

Table 3 Duration of Illness at the Time of Presentation

Duration in months	Number	Percentage
Less than 3	52	19.3
Between 4 to 6	58	21.5
Between 7 to 9	41	[illegible]
Between 10 to 12	30	11.1
Between 13 to 18	27	10.0
Between 19 to 24	20	7.4
More than 24	42	15.5

Spinal segments involved The various regions of the spine involved are shown in Table 4 The order of frequency has been dorsal lumbar cervical and *lumbo*

acral junction There were 25 patients (9 2 per cent) who had involvement of more than one region of the spine each region being separated by two or three normal vertebrae For Table 4 they have been included under the region which had the more advanced lesion Friedman (1966) described 84 spinal lesions in 64 of his patients of tuberculosis of spine Our figures give a rather higher incidence for involvement of cervical spine It is suggested that this may be explained on the basis of the large number of children suffering from spinal tuberculosis in our series cervical spine tuberculosis being more common in children

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Relation between spinal lesion and other visceral and skeletal lesions Like osteo articular tuberculosis spinal tuberculosis is *always the result of a haematogenous* dissemination from a primary focus The primary focus may be active or quiescent apparent or latent either *in the lungs or lymph glands of* mediastinum mesentery or neck or there may be involvement *of other viscera* The detection of the primary focus or an associated visceral lesion greatly depends upon the degree of effort put in this direction In the *present* series a pulmonary lesion could be detected in five per cent of the cases and cervical *lymphadenitis* in seven per cent of the cases The detection of associated visceral lesions in the series of other workers (Konstam 196 Friedman 1966 Wilkinson 1949 and Sanchis Olmos 1948) has been reported to be rather high between 40 and 50 per cent 56 out of 270 patients with spinal tuberculosis (21 per cent) had *disseminated skeletal* lesions either as multiple foci in isolated regions of the spine or with involvement in other regions of the skeleton (Table 5) Ten out of 64 *patients with spinal* tuberculosis in *Friedman's* series (1966) had tuberculous osteomyelitis *of other bones* in addition to the vertebral focus

Vertebral lesion In *the majority of the patients there were the* typical paradiscal lesion characterised by destruction of the adjacent *bone* and end plates of the bodies and the intervening intervertebral disc *The following* uncommon varieties were encountered which may show radiologically intact disc spaces These were the anterior type in two cases (involvement *of* anterior surface only (Figure 1) [illegible] (involvement of pedicles laminae or spinous process) and the central or cystic type of tuberculosis of *body of the* vertebrae in two cases

Abscess and Sinus Tuberculous abscesses were diagnosed on the basis of the characteristic roentgenographic evidence or detection of pus on aspiration or examination and clinical examination of palpable abscess There were 103 cases (i e



Figure 1 Involvement of anterior part of vertebral body associated with psoas abscess shown by moderate bulging of left psoas shadow Intervertebral disc space seems to be uninvolved

about 38 per cent) in the present series who had abscesses or discharging sinuses 63 had abscesses 30 had sinuses and 10 had abscesses and sinuses

Cervical spine abscess Pus from tuberculous cervical spine usually comes to lie in front of the vertebral bodies thus pushing the prevertebral fascia and pharynx and trachea anteriorly (Figure 2)

Thoracic spine abscess The upper thoracic abscess casts a V shaped shadow stripping the lung apices laterally and downwards or when it is small the superior mediastinum shows only squaring of its borders Abscess in the region of 7th cervical to 4th dorsal vertebrae requires good quality X rays to be diagnosed at an early stage Abscesses lower down produce typical fusiform shape (Figure 3) (bird



Figure 2 Tuberculosis of cervical spine (C_4–C) with a large prevertebral abscess



Figure 3 Typical fusiform paravertebral abscess (bird nest appearance) Note minimal involvement of vertebral bodies and intervening disc space (D6–D)

Table 5 Distribution of Various Regions Involved in 56 Cases of Spinal Tuberculosis (Besides Their Major Region of Spinal Involvement)

Oth r region of spine	2
Sacrum and sacroiliac joints	8
Hip joints	9
Knee	3
Foot	4
Hand	3
Elbow	2
Skull	2
Ribs	1
Should r	1
Pubis	1

(The difference between the t tal of above figures (59) and the total number of spinal tuberculosis patients having disseminated skel tal foci (56) is because some of these patients had the disease in multiple regions)

n t appear nce) however when the size of the al c s is too large it may take the shape t a gener li e l l roa l ning of the medi stinum Abscesses or sinuses from ical or l r al regi n c n present them elves far awa from the vertebral co l mn al g the f s ial plains or c urs of neurov s ul r l und es

Lumbar spine abscess Ab ce s s fr m the lumbar spine foll w the well know n patte n f tracki g d wn the p oas sheath Radiological manifestation of psoas l c s un lat al or infrequentl bilateral widening of the p oas shadows how v r it nee ls an excellent quality picture to detect an bulging of the pso s border

Table 6 Usual Causes of Neurological Complications in Caries Spine

	Cause	Course
1	Inflammatory oedema	Recovers by conservative therapy
2	Tuberculous granulation tissue	Recovers by conservative therapy
3	Tuberculous abscess	Recovers by conservative therapy Rarely requires drainage
4	Tuberculous caseous tissue	May subside by conservative therapy Sometimes requires evacuation
5	Tubercular debris	Solid debris requires operative removal
6	Sequestra from vertebral body and disc	Requires operative removal
7	Constriction of cord due to narrowing of vertebral canal	Requires operative decompression
8	Localised pressure due to salient (Internal Gibbus) along anterior wall of vertebral canal	Requires operative decompression
9	Prolonged stretching of the cord over a severe deformity	i) Stretched cord may be more vulnerable to other causes then decompression and release of cord may lead to recovery ii) Rarely stretching leads to interstitial fibrosis (difficult to prove/disprove) which does not recover
10	Infective thrombosis/end arteritis of spinal vessels	Difficult to prove/disprove does not recover
11	Pathological dislocation of spine	Rare complication usually results from rough manipulation by masseur/or indiscriminate laminectomy for caries spine irreparable severence of cord

N B More than one cause may be *acting* in the same case

Spinal cord involvement This is the most dreaded complication of spinal tuberculosis 57 patients (21 1 per cent) in the present series of 270 cases had some degree of neurological involvement at the time of presentation in our department We had

Tuberculosis cervical spine	Quadriparesis	5
– – –	Quadriplegia	2
– dorsal –	Paraparesis	21
– – –	Paraplegia	29
	Total	57

Patients who had neurological complications but were able to walk have been labelled as quadriparesis or paraparesis whereas those unable to walk due to advanced paralysis have been included under the heading of quadriplaegia or paraplaegia

Pathology of neurological involvement Based upon the clinical behaviour and response to conservative therapy radiological observations and the operative findings of the cases who were decompressed we feel that the usual causes of neurological complications in caries spine in order of frequency are as shown in Table 6 The observations in our group are in general agreement with those reported by *Seddon* 1956 *Garceau* 1950 *Griffiths et al* 1956 *Friedman* 1966 *Konstam* 1962 *Hodgson* 1960 It may be pointed out that the apparent deformity of spine has not been significant cause of paraplegia in the present series There are many patients with an extreme degree of deformity without any neurological involvement

TREATMENT AND RESULTS

Over the past few years total extirpation and excision of tuberculous foci in the spine has been practised and advocated by *many workers* (*Hodgson* and his team 1956 1960 *Masalawala* 1963 *Donaldson* 1965) However because of a large number of patients of *osteoarticular tuberculosis* lack of availability of hospital beds operating time and the medical staff we have been mostly treating our patients *on conservative* lines by anti tubercular chemotherapy *rest and* ultimately spinal braces A large majority of the present series have been *treated* as out door patients out of sheer necessity Such facilities *presumably* do not exist in other under developed countries of the *world* either and orthopaedic surgeons working in those places facing similar problems have to resolve to simple methods of treatment (*Konstam* 1962) In our series hospitalisation and surgery has been *restricted* to paraplegics unable to walk and some patients who require drainage of abscesses and other patients who agreed to fusion of *the* spine for an unstable or painful spinal *lesion*

Usual principles of treatment The basis of our treatment consists of

a) Rest in hard bed or plaster of Paris bed for 9 months to 12 months *Plaster of Paris bed* is not essential, however it is necessary for the majority of our patients who do not realise the value of rest When a patient is made to lie down in the plaster of Paris bed *the patient* and his attendants do realise that something grave has happened to the patient and thus they become more cooperative in having the full course of the treatment

b) Drugs An adult is prescribed Inj Streptomycin Gramm 1 I M *daily for 100 Gms (3 months) PAS 12 Gms daily in divided doses for* 18 months INH 300 mgs daily in divided doses for 24 to 30 months Supportive therapy with multi vitamins haematinics if necessary and high protein diet is advised throughout the treatment Doses are modified according to the age

c) *Radiographs* and L S R are *taken* and patients are c*alled* for check up at 3 to 6 months intervals

d) Gradual mobilisation of patients is encouraged with the help of spinal braces after 9 to 12 months of bed rest Spinal brace is continued for about 18 months to 2½ years when it is gradually discarded

The majority of the patients during this period get stable fibrous or bony ankylosis We are still working on the final results of our line of treatment on the vertebral lesion itself Patients who have unstable or painful lesions are advised to have spinal arthrodesis Five patients agreed to spinal fusion posterior spinal arthrodesis was performed and all of them are doing well after the operation

e) Abscesses are aspirated when near the surface and one gramm of streptomycin in solution is instilled at each aspiration Open drainage of the abscess is performed if aspiration fails to clear them All paravertebral abscesses were not drained drainage was incidental whenever a decompression was performed for Pott s paraplegia Prevertebral abscesses in the cervical region have been drained under local anaesthesia when complicated by neurological involvement or difficulty in deglutition and respiration

RESULT

Sinuses in a large majority of cases healed within six weeks to twelve weeks from the onset of the treatment A small number healed with longer treatment and curettage of the tract

Spinal cord involvement and its response to treatment *is shown in* Table 7

Table 7 Behaviour of 57 Cases of Neurological Involvement in Caries Spine

Vertebral level	Degree of neurological involvement		Mode of treatment		Results and remarks
Cervical spine	Quadriparesis	5	Conservative therapy	= 3	Complete recovery
			Conservative + skull traction	= 1	Complete recovery
			Conservative + traction + drainage prevertebral abscess	= 1	Complete recovery
Cervical spine	Quadriplegia	[illegible]	Conservative + traction	= 1	Complete recovery
			Conservative + traction + drainage of prevertebral abscess	= 1	Complete recovery
Dorsal spine	Paraparesis	1	Plaster of Paris bed + conservative	= [illegible]1	Complete recovery
Dorsal spine	Paraplegia	[illegible]	POP bed + conservative	= in all	1[illegible] recovered—Majority younger group and early onset paraplegia 13 did not respond
			Operative decompression performed	in 13	11 complete recovery 1 fair recovery 1 no recovery

NB 21 1 per cent or 57 cases had neurological involvement out of 270 cases of spinal tuberculosis

a) Rest in hard bed or plaster of-Paris bed for 9 months to 12 months Plaster of-Paris bed is not essential, however it is necessary for the majority of our patients who do not realise the value of rest When a patient is made to lie down in the plaster-of-Paris bed the patient and his attendants do realise that something grave has happened to the patient and thus they become more cooperative in having the full course of the treatment

b) Drugs *An adult is prescribed Inj Streptomycin Gramm 1 I M* daily for 100 Gms (3 months) PAS 12 Gms daily in divided doses for 18 months INH *300* mgs daily in divided doses for *24* to *30* months Supportive therapy with multivitamins haematinics if necessary and high protein diet is advised throughout the treatment Doses are modified according to the age

c) Radiographs and L S R are taken and patients are called for check up at 3 to 6 months intervals

d) Gradual mobilisation of patients is encouraged with the help of spinal braces after 9 to 12 months of bed rest Spinal brace is continued for about 18 months to 2½ years when it is gradually discarded

The majority of the patients during this period get stable fibrous or bony ankylosis We are still working on the final results of our line of treatment on the vertebral lesion itself Patients who have unstable or painful lesions are *advised to have spinal arthrodesis Five patients* agreed to spinal fusion posterior spinal arthrodesis was performed and all of them are doing well after the operation

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RESULT

Sinuses in a large majority of cases *healed within six weeks to twelve* weeks from the onset of the treatment A small number healed with longer treatment and curettage of the tract

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progressive recovery to a satisfactory level after a fair trial of conservative therapy for a few weeks (4 to 6 weeks) or the cases in which the patients developed neurological complications during the conservative therapy or in which paraplegia became worse while the patient was undergoing treatment with anti tubercular drugs and bed rest In other words we have performed decompression for absolute indications of Pott s paraplegia We have not performed this procedure only for excisional therapy of tuberculous spine In the cervical spine drainage for prevertebral abscess was performed in two cases and skull traction was applied in four patients of neurological involvement in the upper dorsal spine we prefer anterior spinal decompression through a trans thoracic transpleural approach as anterolateral decompression does not provide a wide exposure from 4th dorsal to 12th dorsal region anterolateral decompression has been performed Operative decompression was performed in 13 cases of Pott s paraplegia 11 of them recovered completely one recovered enough to be able to walk with residual spasticity and one unfortunately did not recover Fortunately we did not have any operative or postoperative mortality in the operated cases

We feel that a judicious combination of anti tubercular drugs has decreased the indications for universal surgical excisional therapy of tuberculous lesions The majority of the patients can be safely treated on domiciliary regime Spinal tuberculosis is only a localised manifestation of a systemic infection and thus no local surgical procedure is a substitute for adequate and prolonged systemic anti tuberculous drug therapy In the light of the present observations and those of *Konstam* (1962) and *Friedman* (1966) the use of a judicious combination of anti tubercular drugs should reduce the indications of surgery in spinal tuberculosis to the following (i) Pott s paraplegia not showing signs of progressive recovery to a satisfactory level after a fair trial of conservative therapy (4 6 weeks) (ii) cases of caries spine who developed paraplegia during the conservative treatment (iii) those cases where paraplegia becomes worse while the patient is undergoing therapy with anti tubercular drugs and bed rest (iv) patients who have unstable spinal lesions or have painful ankylosis of spine (v) cases of prevertebral cervical abscesses with neurological signs and difficulty in deglutition and respiration (vi) accessible abscesses not clearing with repeated aspiration and anti tubercular drugs and tubercular sinuses not responding to conservative therapy

21 1 per cent of our patients had neurological involvement Over all incidence of this complication given by *Girdlestone* (1952) and *Griffiths* (1952) is 10 per cent and 11 per cent respectively, in all cases of spinal caries

DISCUSSION

Treatment of spinal tuberculosis in different parts of the world ranges from sophisticated sanitorium treatment under drug cover (*Kaplan* 1959 *Friedman* 1966) to varying degrees of radical surgery combined with anti tuberculous drug treatment (*Seddon* 1956 *Roaf* 1958 1959 *Hodgson* 1960 *Mukopadhaya* 1956 1957 *Masalawala* 1963 *Donaldson* 1965) Introduction of judicious combination of Streptomycin PAS and INH has revolutionised the treatment of spinal tuberculosis and has markedly improved the results of conservative treatment and less radical surgical approach The ability of antituberculous drugs to reach the actual site of tuberculous lesion has long been doubted However recent studies by various workers (*Barclay et al* 1953) using radio active tagged isoniazid showed that this drug is freely diffusable into all tissues including bone as well as into tuberculous abscess cavities and caseous material It may be presumed that besides INH other anti tubercular drugs also reach the site of tuberculous lesions Moreover the clinical response of spinal disease under anti tubercular chemo therapeutic agents leads one to infer that these drugs indeed reach the site of infection Many cold abscesses treated by anti tubercular agents in the series of various workers have been proved to be sterile to the usual methods of culture and guinea pig inoculation

The use of these drugs has permitted major excisional surgery with greater safety However universal total extirpation of tuberculous lesions in the spine has been practised and advocated by many workers (*Hodgson & Stock* 1956 *Hodgson et al* 1960 *Wilkinson* 1950 *Mukopadhya* 1956) on the supposition that drugs are unable to reach the site of a tuberculous lesion

It is revealing to study the behaviour of neurological complications in our present series The majority of our cases recovered on conservative therapy and surgical decompression in them was unnecessary It must be pointed out that the majority of these patients who made a progressive recovery by conservative therapy alone were patients with neurological complications of early onset and they belonged to a young er age group We have been performing decompression of cord only for those cases of tuberculous paraplegia who did not show signs of

progressive recovery to a satisfactory level after a fair trial of conservative therapy for a few weeks (4 to 6 weeks) or the cases in which the patients developed neurological complications during the conservative therapy or in which paraplegia became worse while the patient was undergoing treatment with anti tubercular drugs and bed rest In other words we have performed decompression for absolute indications of Pott's paraplegia We have not performed this procedure only for excisional therapy of tuberculous spine In the cervical spine drainage for prevertebral abscess was performed in two cases and skull traction was applied in four patients of neurological involvement in the upper dorsal spine we prefer anterior spinal decompression through a transthoracic transpleural approach as anterolateral decompression does not provide a wide exposure from 4th dorsal to 12th dorsal region anterolateral decompression has been performed Operative decompression was performed in 13 cases of Pott's paraplegia 11 of them recovered completely one recovered enough to be able to walk with residual spasticity and one unfortunately did not recover Fortunately we did not have any operative or postoperative mortality in the operated cases

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Fällen auf jene Patienten die schmerzvolle oder unstabile Schädigungen der Wirbelsäule hatten und mit einer spinalen Arthrodese einverstanden waren beschrankt Die Ergebnisse die wir bei unserem vorliegenden Material erzielten lassen sich in vorteilhafter Weise mit denen die nach radikaler chirurgischer Behandlung und sorgfaltigerer Überwachung im Sanatorium berichtet werden vergleichen

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SUMMARY

Osteoarticular tuberculosis in general and spinal tuberculosis in particular still remains one of the major problems to be dealt with in any orthopaedic centre in our country We have treated the majority of our cases as out door patients with anti tubercular drugs and rest at home under conditions far from sanitoria Surgery and admissions to the hospital have been restricted out of necessity to cases whose abscesses were not resolving by repeated aspiration or cases of neurological complications due to caries spine requiring an operative decompression or rarely for those patients who had painful or unstable lesions in the spine who agreed to spinal arthrodesis The results obtained in our present series are to be compared favourably with those reported in series treated by radical surgery and a more elaborate sanitorium regime

RESUME

La tuberculose ostéoarticulaire en général et la tuberculose vertébrale en particulier restent toujours les problemes majeurs dont il faut s'occuper dans chaque centre orthopedique de notre pays Nous avons traité la majorite de nos cas avec des medicaments antituberculeux à la maison dans des conditions loin de ressembler à celles des sanatoria Les interventions chirurgicales et l'hospitalisation se sont bornées aux cas ou des complications neurologiques provoquees par des caries vertebrales necessitaient une opération de decompression ou plus rarement chez des malades ayant des lesions douloureuses et instables de la colonne vertebrale et decides à accepter une arthrodèse vertebrale Les resultats obtenus dans nos présentes series sont favorables par comparaison à ceux rapportes dans les series traitées par chirurgie radicale et un regime plus etudie de sanatorium

ZUSAMMENFASSUNG

Gelenks und Knochentuberkulose im allgemeinen und Wirbelsäulentuberkulose im besonderen verbleibt noch immer eines der grosseren Probleme in jedem orthopädischen Zentrum in unserem Lande Wir haben die Mehrzahl der Fälle ausserhalb des Krankenhauses mit antituberkulosen Mitteln und Ruhe daheim behandelt Chirurgie und Aufnahme ins Krankenhaus wurden aus Gründen der Notwendigkeit auf Fälle mit neurologischen Komplikationen wegen Karies der Wirbelsäule die eine operative Dekompression erforderten oder in seltenen

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EDEN HYBBINETTE'S OPERATION FOR RECURRENT DISLOCATION OF THE HUMERO SCAPULAR JOINT

By

JAMES HINDMARSH & ALF LINDBERG

Received 28 IX 66

In this study an account is given of the results of a clinical and radio logical follow up of a series operated on according to Eden Hybbinette in consequence of recurrent anterior luxation of the humero scapular joint

SERIES

The series is formed of all patients who were operated on owing to recurrent shoulder dislocation in Surgical Department I Södersjuk huset during the period 1948-1963 and consists of 119 patients in cluding 77 men and 42 women One patient was operated on bilaterally so that the number of shoulders is 120 58 right and 62 left shoulders

The pre operative information is collocated in Tables 1-5 Table 1 the usual excess representation of low ages is found at the first dis location here it is 89 per cent below 40 years of age 11 shoulders were dislocated primarily without trauma = 9 2 per cent while in 6 cases there was no definite information whether the first dislocation occurred in association with trauma

Table 2 the degree of severity of the initial trauma is difficult to evaluate afterwards so that only a rough division into two groups could be made 6 cases could not even be placed in one of these 8 shoulders were reduced by laymen 71 by doctors and with few excep tions under narcosis Spontaneous reduction was relatively somewhat more common with slight than with more severe trauma Details con cerning the reduction are lacking in 6 cases

Table 3 although the details must be taken with some reservation owing to the frequently long period of time between the first disloca

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Table 4 Type of trauma at 1st dislocation (103 traumatic cases)

Fall on extended arm	48
Excessive rotation of abd. arm	15
Trauma from the rear directly against the shoulder or indirectly via the elbow	14
Throw effect or jerk on forward raised arm	4
Forced passive rear movement of abd arm	4
Uncertain	18
	103

Table 5 Duration of anamnesis No of dislocations

Anamnesis duration	No of cases	No of dislocations <5	5 10	11 20	>20
<1 year	8	1	2	3	2
1 3 years	27	6	15	4	2
3 5 years	26	6	13	5	2
5 10 years	26	3	8	9	6
>10 years	33	3	12	6	12
	120	19	50	27	24

Table 5 the anamnesis is quite long on average (more than 5 years in almost half of the cases) In cases previously operated outside this series which recurred (7 in number) the length of the anamnesis (period from first dislocation to operation) and the number of dislocations were calculated up to operation in this series

OTHER PRE OPERATIVE INFORMATION

13 patients had bilateral recurrent shoulder dislocation One was operated on bilaterally in this series 4 were operated on the second shoulder at a different hospital and 8 were *not operated* on the second shoulder One of the 8 nonoperated patients has had freedom from recurrence for one year the remaining 7 for between 4 and 16 years (In addition to these 13 cases of bilateral recurrent dislocation 3 pateient had dislocated the second shoulder once)

4 patients had epilepsy

8 out of 113 patients (= 7 1 per cent) who were asked this question stated that there was familial connection with *recurrent* shoulder dislocation No case had a history of massive heredity but patients *referred to one relative* only who had the condition (5 to a brother or *sister* 2 to a cousin and 1 to a grandmother) All 8 patients had sufficient trauma on the first dislocation and only one had a bilateral condition (second shoulder not *operated on*) 7 patients were operated in this series because the condition recurred after a previous operation at a different hospital 3 of them had been operated on according to Camitz 2 according to Eden Hybbinette one according to Orell and *one according* to Magnuson

tion and the operation it is nevertheless obvious that the period of fixation on average was short and only exceptionally extended to 3 weeks.

Table 4: a surprising number of patients remembered the initial trauma well and could give a fairly adequate description of the mechanism of injury. The series illustrated the fact, long well known, that recurrent dislocations may be the consequence of varying types of initial force. Falls onto an extended arm dominated among these and were reported by almost half of the patients.

Table 1. Age at 1st dislocation. Traumatic and atraumatic cases.

Age at 1st dislocation	No. of cases	Trauma	0 trauma	Uncertain
< 20 years	46	38	5	3
20–39 years	61	53	5	3
40–60 years	13	12	1	0
	120	103	11	6

Table 2. The initial trauma. Reduction at 1st dislocation.

	No. cases	Self-reduct.	Red. doct. or layman	No inform.
No or slight initial trauma	25	9	16	0
More severe initial trauma	89	23	62	4
Uncertain degree of severity	6	3	1	2
	120	35	79	6

Table 3. Immobilisation on 1st dislocation.

No fixation	41
Sling max. 1 week	20
Sling 1–2 weeks	20
Sling 2–3 weeks	7
Sling >3 weeks	5
Fixation to trunk 1–2 weeks	13
Fixation to trunk at least 3 weeks	7
No information	7
	120

96 cases Other operative findings of interest were the description of a capsular pouch before the neck of the scapula in 34 cases of a rounded or worn anterior rim of the glenoid in 14 shoulders and of arthrosis in 4 shoulders In a few cases the surgeon stated that he could palpate a posterior defect in the humeral head

METHODS

Clinical Follow up

A stencilled questionnaire was sent out to all 119 patients in which each patient had to answer questions on possible recurrence ability to work strength and mobility in the operated shoulder as well as subjective trouble in the form of aching or pain on movement Answers were received from 113 patients representing 114 operated shoulders = 95 per cent of the whole material 7 patients who could not appear for the follow up were also interviewed by telephone The remaining 106 were examined clinically 102 by the author and 4 by willing colleagues at other hospitals

The observation periods can be seen in Table 6 The average observation period was 8 5 years (variation 2 17 5 years)

Table 6 Observation periods (114 shoulders examined)

2 3 years	14
3-5 years	20
5 10 years	36
>10 years	44
	114

Radiological Follow up

In connection with the clinical follow up 10 patients were X rayed (one of these was operated on bilaterally *in this series*)

The purpose of the X ray examination was to obtain information concerning possible arthrosis in the humero scapular joint and its degree of severity to identify the transplant to demonstrate *the possible* occurrence of ossifications in the humero scapular joint or its immediate *surroundings* to demonstrate the presence of a posterolateral compression *cavity and possible* anatomical abnormalities which might indicate a disposition to recurrent shoulder *dislocation*

Radiological Technique

Both shoulders were examined according to the same technique and the following three projections were used in all cases

1 Frontal (antero posterior) *projection* the arm is rotated inward approx 60 degrees and the X ray tube is angled 15 *degrees* from above

2 "Stryker" or "notch view" *the arm lifted* forward and upward with the elbow bent and the palm of the hand *on the neck while* the tube is angled 10 degrees from below This projection gives a profile *picture* of the postero superior and the antero inferior area of the humoral head and the anatomical neck

OPERATIVE TECHNIQUE AND POSTOPERATIVE TREATMENT

All 120 shoulders in this series were operated on according to Eden-Hybbinette following the technique described by Palmer and Widén in 1948. Its main feature is that a hook-shaped transplant (J- or J-form) taken from the iliac crest is inserted into a subperiosteal pocket prepared with a raspatory along the *anterior aspect of the neck of* the scapula; the transplant is so shaped that with the best possible adjustment its short leg can be hooked up on the anterior rim of the glenoid. In those not infrequently occurring cases in which the labrum was missing and the periosteum was torn away within a fairly large area of the neck of the *scapula the fixation of the transplant was not so* good but no attempt was ever made to carry out any form of osteosynthesis. The capsule and the subscapularis tendon were sutured together in one layer with strong mattress sutures and the arm was inward rotated. (The procedure involves a degree of raphe but the shortening of these structures is not of course so marked as if they are sutured with overlapping.)

The post-operative treatment was also fairly uniform. The arm was fixed to the body with a cushion underneath the axilla for 2–3 weeks. Afterwards abduction movements were permitted in an arm sling although outward-rotation was avoided for 4–6 weeks. After this period the patient was encouraged to take up active exercises without reservation. The period of hospital care varied from 4 to 20 days but was with few exceptions 6–11 days.

POST-OPERATIVE COMPLICATIONS

Only one post-operative complication occurred and this was a mild *wound infection* without any effect on the operative result.

OPERATIVE FINDINGS

The documentary value of accounts of operations must be considered to be limited in a follow-up investigation which has not been planned beforehand and with several surgeons involved (9 surgeons in this series). Information concerning possible pathological findings may be incomplete *and interpretation of them vary*. Information concerning the labrum is to be found in 111 reports. It was stated to be intact in 29 cases, detached or ruptured in 46 and to be completely missing in



Figure 3 United transplant in frontal (left) and inferior superior (right) projection 17 years after op

the arthrosis and these were mainly based on an estimation of the relative size of the osteophytes and the possible presence of sclerosis in skeletal structures near the joint

Slight arthrosis fairly small osteophytes on the edges of the articular surfaces were the only finding

Moderate arthrosis medium sized osteophytes were the only finding There were medium sized or minor osteophytes in association with lesser degrees of sclerosis in skeletal structures near the joint (Figure 1)

Severe arthrosis there were large or fairly large osteophytes on the articular surface edges in association with severe degrees of cartilage reduction and sclerosis in adjacent skeletal part (Figure 2)

Evaluation of the transplant

The transplant was judged to be united when it could be identified as a rim of bone which projected above the anterior caudal area of the glenoid and which could be distinguished with certainty from an osteophyte (Figure 3)

RESULTS

Recurrence

One patient had recurrence 3 years after operation without adequate trauma After almost 10 further dislocations the patient was operated on by means of the same method (Eden Hybbinette s operation) A large capsular pouch was found which had also been observed at the first operation The transplant had been resorbed for the greater part and the small remnant had a cartilage like appearance At follow up 6 years after the last operation the result was excellent and no further recurrence had occurred The new transplant had united



Figure 1 Moderate arthrosis 16 years after op No subj symptoms End result excellent

Figure 2 Severe arthrosis 14 years after op No subj symptoms End result excellent



3 Lateral (axillary inferior superior) projection the cassette is placed like an epaulette above the shoulder the arm is abducted 90 degrees and pronated the X ray tube is angled directly from below centring on the axilla This projection described by *Jakobsson* (1950) allows an evaluation of the anterior rim of the glenoid

The tangential epaulette picture described by *Hermodsson* (1934) where the arm is maximally rotated inward would also have been interesting above all in demonstrating the postero lateral compression cavity To avoid further complications in the follow up examination which was undertaken by a department heavily involved in normal routine the radiological diagnostic procedure however had to be confined to the three projections enumerated

Classification of the degree of arthrosis

The evaluation of the extent of the cartilage damage was naturally not often possible with the X ray technique used Attempts were made however to classify



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One patient suffered a fresh dislocation 16 weeks after operation as a consequence of a considerable trauma (fell headlong from a height of 2 metres and broke his fall with his hand). Reduction was spontaneous. The patient has never dislocated his shoulder since and the end result was excellent at the follow up examination 16 years after operation and the transplant was united.

Recurrence of the *condition has therefore only occurred in one case* out of 114 shoulders which were followed up = 0.88 per cent.

Results of the Clinical Follow up

The results referring to subjective symptoms and mobility are collocated in Table 7.

The following characteristic examples of slight subjective discomfort may be mentioned: slight pain on certain movements, slight aching with changes of weather or after heavy work, some tiredness associated with heavy or lengthy work, insignificant limitation of function owing to slightly reduced strength or mobility. All the patients in group B stated that they had full working capacity.

Table 7. Subj. symptoms and range of movement

Subj. symptoms	No. of cases	Mobility 1. Free/slight limitation	 2. Moderate limitation	 3. Considerable limitation
A. None	64	57	7	0
B. Slight	44	34§	10	0
C. More severe	6	0	3†	3
	114	91	20	3

5 by letter   *§ 1 by letter*   *† 1 by letter*

*Amongst the 6 patients who had severer subjective troubles 2 attri*buted this solely to reduced mobility and strength, 2 had in addition slight periodic aching *and tenderness in the shoulder, while 2 had* severer periodic aching. *One of the latter two had a cervical disc syn*drome [illegible] with *pain in the same arm and had been operated on for* arthrosis in the acromioclavicular joint with a clavicle resection on the same side, *the other had rheumatoid arthritis which had shown* symptoms from the shoulder before the first dislocation. Only one patient had had a change *of occupation owing to residual trouble after*

the operation, while one (a woman) had finished with her trade for this reason.

Group 1 includes shoulders with a maximum of 20 degrees limitation of elevation and/or outward rotation.

Group 2 comprises cases with an elevation of 90–160 degrees and/or an outward rotation of 45–70 degrees.

Three patients (group 3) had still greater limitation of mobility both in elevation and rotation but no one had an ankylosis.

Table 8. Classification of end results. Average observation period for the respective groups.

Results	No. of cases	A 1	B 1	A 2	B 2	C 2	C 3	Av. obs. period (yrs)
Excellent	57	57	0	0	0	0	0	9.2
Good	41	0	34	7	0	0	0	7.8
Satisfactory	13	0	0	0	10	3	0	8.1
Unsatisfactory	3	0	0	0	0	0	3	
	114							

In evaluating the clinical end result (Table 8) both objective and subjective symptoms were taken into consideration. Therefore in 7 cases which had moderate limitation of mobility, mainly rotation, but no subjective symptoms *the end result* was judged good, and three cases belonging to group C were classified satisfactory although the subjective trouble admittedly could not be designated slight while yet being of moderate severity, and since the patients themselves were satisfied with the result of the operation. According to these criteria therefore the end result was *excellent or good in approx.* 86 per cent, satisfactory in 11 per cent and unsatisfactory in 3 per cent. In cases which were observed for a long period no tendency towards a deterioration in the results was seen.

Results of the Radiological Follow-up

Pre-operative films were sought in the 105 cases (106 shoulders operated) which were X-rayed during the follow-up. This gave positive results for 54 shoulders, while in 39 cases only the radiological reports were available. Neither films nor reports could be traced in the case of 13 shoulders.

One patient suffered a fresh dislocation 16 weeks after operation as a consequence of a considerable trauma (fell headlong from a height of 2 metres and broke his fall with his hand). Reduction was spontaneous. The patient has never dislocated his shoulder since and the end result was excellent at the follow up examination 15 years after operation and the transplant was united.

Recurrence of the condition has therefore only occurred in one case out of 114 shoulders which were followed up = *0.88 per cent*.

Results of the Clinical Follow up

The results referring to subjective symptoms and mobility are collected in Table 7.

The following characteristic examples of slight subjective discomfort may be mentioned: slight pain on certain movements, slight aching with changes of weather or after heavy work, some tiredness associated with heavy or lengthy work, insignificant limitation of function owing *to slightly reduced strength or mobility. All the patients in group B* stated that they had full working capacity.

Table 7. Subj. symptoms and range of movement

Subj. symptoms	No. of case	Mobility: 1 Free/slight limitation	2 Moderate limitation	3 Considerable limitation
A None	64	57	7	0
B Slight	44	34*	10	0
C More severe	6	0	3†	3
	114	91	20	3

5 by letter   [illegible] letter   1 by letter

*Amongst the 6 patients who had severer subjective troubles 2 attri*buted this solely to reduced mobility and strength, 2 had in addition slight periodic aching and tenderness in the shoulder, while 2 had severer periodic aching. One of the latter two had a cervical disc syndrome later with pain in the same arm and had been operated on for arthrosis in the acromioclavicular joint with a clavicle resection on the same side; the other had rheumatoid arthritis which had shown symptoms from the shoulder before the first dislocation. Only one patient had had a change of occupation owing to residual trouble after

the shape of the rim of the glenoid since axial projections were lacking. In no case could any noteworthy skeletal anomalies be demonstrated.

In Table 10 the frequency of arthrosis in the humero-scapular joint and of posterolateral defect in the humeral head in the radiological follow-up (210 shoulders) is stated. It will be seen from the table that moderate or severe arthrosis was present in approx. 72 per cent of the shoulders operated in this series while the figure for non-dislocated shoulders (group a) was approx. 7 per cent, a ratio of approx. 10:1. The figures for dislocated non-operated shoulders (group b and c) and shoulders operated outside the series (group d) are too small to allow conclusions to be drawn even if an increased disposition to arthrosis in group b + c as compared with group a can be noted and in group d when compared with group c.

No posterolateral defect could be found in 18 cases operated in this series nor in any of the shoulders which had never been dislocated.

In 79 cases the transplant had united at the site where it had been placed at operation while in 27 cases it could not be identified.

In 19 shoulders one or more capsular ossifications could be seen. Definite conclusions concerning their origin could not be drawn. They could for example be an expression of athrosis, they could be determined by a loosened transplant, calcification of the labrum or fragments following a previous fracture of the rim of the glenoid. In 8 cases which had non-united transplant and a single large capsular ossification it was considered probable that this was formed by the transplant. Moreover in the two shoulders which were re-operated on in this series after previous operation according to Eden-Hybbinette a capsular ossification appeared in addition to the new united transplant and this ossification in all probability consisted of remnant of the old non-united transplant. In one of these cases the old transplant was found on operation to be *firmly grown* into the anterior capsular wall where it was visible at the follow-up. In the second case no trace of the old transplant was found at operation but radiology revealed a 3 cm long osseous body in the soft tissue caudally of the glenoid cavity.

Dysplasia of the caput or cavity which could be interpreted as a disturbance of development was not demonstrated in any one case.

In Tables 11 and 12 the relationships between subjective symptoms and clinical end results respectively and arthrosis in the humero-scapular joint are shown. (Slight arthrosis was considered to have no significance in this connection and was made the equivalent of no arthrosis.) The dominating incidence of moderate to severe arthrosis even with the absence of subjective symptoms and with excellent end results is striking. Out of a total of 22 cases with severe arthrosis 19 declared that they had no or only slight subjective symptoms and the

Table 9 Radiological findings concerning arthrosis in the humero scapular joint and postero lateral defect before operation and at the follow up of 93 shoulders

	Postero lat defect	0 arth	Slight arth	Mod arth	Severe arth
Pre operative X ray	54	74	13	5	1
Post operative X ray	78	13	16	44	20

Table 9 groups information concerning arthrosis in the humero scapular joint and posterolateral defect in the humeral head in pre-operative radiology of 93 shoulders and compares this with post operative radiological findings for the same shoulders The larger number of posterolateral defects found in postoperative radiology is probably explained by the better radiological technique used in this investigation than in the pre operative one The pre operative films which were examined were taken with few exceptions in two projections only that is frontal with inward rotated arm and lateral and this is probably also true of those X-rays of which only the reports have been recovered The same conditions may also have affected the number of arthroses demonstrated but the difference in the number of cases of moderate and severe arthrosis in pre and postoperative radiology is far too great to be explained by a variation in radiological technique As a rule the pre operative films did not produce any more certain evaluation of

Table 10 Radiological findings on arthrosis in the humero scapular joint and postero lateral defect at the follow up (210 shoulders)

	A Operated shoulder the series (100)	B Second shoulder (104) [illegible] (90)	[illegible] (3)	[illegible]	[illegible] recur disloc [illegible] series (4 [illegible])
0 arthrosis	13	64	1	4	1
Slight arthrosis	17	20	1	[illegible]	1
Moderate arthr	54		1	1	
Severe arthr	2[illegible]	1	0	0	[illegible]
Posterolateral defect present	[illegible]8	0		4	4
Posterolateral defect absent	18	90	1	[illegible]	0

All according to Eden Hybinette

Table 13. Arthrosis in the humero-scapular joint in relation to the duration of anamnesis and observation period, number of dislocations, united and non-united transplants (72 cases, see text)

		No. of cases	No or slight arthrosis	Moderate or severe arthrosis
Duration of anamnesis	< 5	44	18	26
Duration of anamnesis	> 5	28	10	18
Observation period	< 5	31	17	14
Observation period	> 5	41	11	30
No. of dislocations	< 10	46	22	24
No. of dislocations	> 10	26	[illegible]	0
Transplants united*		4	22	32
Transplants not identified		18	6	12

Since the genesis of arthrosis is probably dependent upon a large number of combined factors, the figures in Table 13 must be evaluated with care and in no case be regarded as providing conclusive proof. With this reservation it may be pointed out that the occurrence of moderate to severe arthrosis seems to have a certain correlation to the length of the observation period but on the other hand scarcely to the length of the anamnesis if the material is divided on either side of a 5-year limit. The figures also argue in favour of a connection between such arthrosis and the number of dislocations at a limit of 10. On the other hand no significant difference existed respecting the incidence of striking arthrosis between the group where the transplant could be seen projecting over the cavity rim and the group in which it could not be identified.

DISCUSSION

The intention of this study is not to try to elucidate the etiology of recurrent shoulder dislocation. Some reflections may be made, however, on the importance of various possible etiological factors.

Bankart's theory concerning detachment of the labrum as the essential injury is contradicted to a certain extent by the results presented by De Palma. The latter found at autopsy of a large material consisting of previously non-dislocated, nor otherwise injured shoulders, an incidence of labrum detachment which rose with age, so that the injury was most common in those age groups in which recurrent dislocation is rare. It is of course possible that a traumatically con-

Table 11 Subjective symptoms in relation to arthrosis in the humero scapular joint (106 op shoulders followed up)

	No of cases	0 or slight arthrosis	Moderate arthrosis	Severe arthrosis
No subj symptoms	58	17	30	11
Slight subj symptoms	43	13	22	8
Severe subj symptoms	5	0	2	3
	106	30	54	22

Table 12 Clinical end results in relation to arthrosis in the humero scapular joint

	No of cases	0 or slight arthrosis	Moderate arthrosis	Severe arthrosis
Excellent	51	16	26	9
Good	40	10	24	6
Satisfactory	12	4	3	5
Unsatisfactory	3	0	1	2
	106	30	54	22

clinical end result was judged to be excellent or good in 15 of them The presence of severe arthrosis was however considerably more common in the group *satisfactory unsatisfactory than in the group* excellent good (7 out of 15 as against 15 of 91)

The relationships between arthrosis and a few factors of possible importance in its genesis are shown in Table 13 Here only those shoulders with *confirmed arthrosis have been included in* which any other cause of arthrosis but recurrent dislocation and or treatment of this condition by an operation according to Eden Hybbinette was regarded as improbable Consequently shoulders operated on twice (7) were *excluded* and also cases with another injury or disease in the operated shoulder (3 one of which had rheumatoid arthritis one had been operated on with a clavicle resection owing to arthrosis in the acromio clavicular joint and one had incurred a fracture of the greater tubercle 12 years before the first dislocation) together with all cases with arthrosis in the second non dislocated or injured shoulder (24) Out of the 24 with arthrosis in both shoulders this was more severe in the shoulder operated on in 22 cases 22 of these 24 patients were aged more than 39 at the follow up

In the later literature more care was taken in evaluating the significance of various etiologic factors. *Brav* (1955) declared "there is no common cause of the condition", and Moseley writes that "several factors are present in varying degrees". Taking into consideration the often rather contradictory information in the literature concerning the incidence and degree of various pathologico-anatomical changes it appears probable that the opinion of these authors is correct. If, however, we consider that we are generally justified in talking about an essential lesion (defined as the main etiologic factor in the majority of cases) De Palma's theory undeniably seems to be the most plausible. In the shoulder joint, where the glenoid cavity only embraces ¼ of the humeral head, in which full stability may exist without restriction of mobility in spite of total detachment of the labrum and a large posterolateral defect and where the fibrous capsule is spacious enough to include two humeral heads, it seems reasonable to accept that the stability is mainly dependent on the tone of the surrounding musculature. It also seems reasonable to consider the fibrous capsule with its anterior strengthening gleno-humeral ligament and the subscapularis muscle, the tendon of which is firmly inserted in the capsule, to be a functional unity ("anterior capsular mechanism" according to Moseley) and to assume that these structures can be overstretched and lengthened at the 1st dislocation, especially in younger individuals, in whom they are elastic. Arthrographic studies (*Pettersson* 1942 and others) have revealed that the capsule in "habitual" dislocation is as a rule dilated, particularly in its anterior and lower part. Neuro-muscular unbalance, which is presumed to be the consequence of this "healing with lengthening", is difficult to record objectively (electrophysiological research may perhaps provide us with a chance to do so) but clinical observations indicate its great importance. Thus it is not unusual that these patients can practice in competitive athletics without mishap but may on the other hand experience a recurrence through an everyday action. In our series there was, for example, a patient who was a ski jumper and one who was a competition gymnast, both of whom could dislocate their shoulders when they were putting on their coats. Moseley declares that professional athletes often want to postpone the operation "until the end of their active careers". The proprioceptive signal system is clearly restored after a successful operation, for even if some patients state that they go carefully with the shoulder after the operation, the great majority says (those also with completely recovered mobility) that they never "think about the shoulder". *Moberg* (1957)

ditioned avulsion of the labrum in younger years has a different significance from the injury conditioned by degenerative changes *in older* people, yet the lesion is already fairly common between 30 and 40 years of age. In this series the labrum was intact according to operation reports in about every 4th case.

Palmer & Widen (1948) presented a theory based on the compression fracture (which they found in all their 60 cases) situated postero-laterally in the humeral head, regarding this fracture as the essential etiological factor. They emphasised that "recurrent dislocation is an intracapsular subluxation which occurs when the anterior rim of the glenoid slides into the hollow in the humeral head". The majority of later authors have agreed with Palmer & Widen that *an intracapsular dislocation* is involved, while they have doubted the great importance of the compression hollow and preferred to regard this as a consequence and not as a cause of the recurrence. In various accounts the hollow was found in from 60 per cent to 100 per cent, obviously dependent on the radiological technique used. *Hermodsson*'s (1934) very detailed radiological studies argued clearly in favour of the theory that the defect arose through compression against the lower edge of the glenoid at the 1st dislocation and then did not appreciably increase in size as a result of recurrence, and he found the defect in all his 23 cases of recurrent dislocation. He also discovered the defect, however, in a very large group of the cases which had no recurrence and therefore he did not attribute any great causal importance to it. In this series the defect could be demonstrated at the follow-up in 88 out of 106 cases (= 83 per cent). It is probable that more defects would have been revealed if Hermodsson's tangential projection had also been used. In Moseley's monograph (1961) it is stated that "a compression hollow can be demonstrated in all cases of recurrent anterior dislocation *but obviously* it may be very small, since no less than 5 different projections are required for this 100 per cent *distribution*". Nor could the size of the defect be determined with any great certainty with all these projections. The etiological significance of the postero-lateral compression fracture must continue to be described as not clear.

De Palma (1950) drew attention to the short rotators of the joint which in his opinion are much *overstretched at the first dislocation* (especially the subscapularis tendon) and afterwards do not regain normal length and tone, possibly owing to incorrect treatment, so that a condition of "neuromuscular imbalance" sets in with consequential recurrence.

can probably only produce reliable results if measures are taken to diminish the range of outward rotation to a considerable extent (*e g*, Magnuson s operation) A great limitation of outward rotation cannot however be regarded as irrelevant for these patients who are usually young and often athletes

The results of the Eden Hybbinette operation can also be regarded as satisfactory from a functional point of view In this series 80 per cent of the patients had almost normal mobility Similar results are reported by *Hellens* (1947) *Palmer & Widen* (1948) *Jakobsson* (1949) *Hedman* (1952) Putti Platt s method on the other hand produces according to most information in the literature (*Crawford Adams Osmond Clarke* and others) a fairly substantial restriction of outward rotation This is probably associated with the fact that the subscapularis tendon is shortened in this method through overlapping Bankart s method seems in this respect to be more favourable than Putti Platt s but possibly not as favourable as Eden Hybbinette s

As far as the results of the radiological follow up are concerned the high incidence of arthrosis is notable This series diverges in this respect from those previously published Von Hellens found only 7 arthrotic cases out of 75 shoulders X rayed Jakobsson 5 out of 38 Hedman 1 out of 28 and *Lavik* (1961) 5 out of 22 The difference between this series and those of the authors mentioned is surprisingly large However it can probably be explained partly by the longer period of observation on average in this series partly by differences in radiological technique and possibly also in radiological evaluation A comparison with the second shoulder which was made here with identical projections certainly makes possible a sharpening of diagnostics

Even if the causes of arthrosis are many and difficult to evaluate one can scarcely avoid the impression that the operation as such plays a part in its appearance Indications of this are the slight incidence of arthrosis at operation and in pre operative radiology by comparison with that at the follow up and also the convincing correlation between the length of the observation period and the manifestation of arthrosis Bearing in mind the figures in this series one naturally asks whether Eden Hybbinette s operation is unfavourable *as far* as arthrosis is concerned when compared with other methods The risk of arthrosis has in fact been claimed as an argument against the bone block method The above question must however be left unanswered since no information regarding the incidence of arthrosis on the follow up

presumes that this restoration occurs as a result of a certain shortening owing to scar formation of the anterior capsular structures. The same author points out that the most reliable method of achieving scar formation is free bone transplantation.

A much discussed but little clarified question which may be brought up in this connection is that of the importance of the fixation period at the first dislocation. In consequence of his opinion that overstretching of the subscapularis tendon takes place at the primary dislocation, De Palma recommends lengthy (8 weeks) immobilisation in adduction and inward rotation, while other authors doubt that the period of immmobilisation has any great importance in the risk of recurrence. *Rowe* (1956) found that although this period was of secondary importance compared with the age factor, yet a considerably higher incidence of recurrence could be stated amongst those fixed less than a week than amongst those fixed over a longer period. Amongst those who had more than a week's fixation the differences were quite small, although the best prognosis was for those shoulders which were fixed to the trunk for 3 weeks or immobilised by arm sling alone for 4 weeks, while a further lengthening of the fixation period did not diminish the risk of recurrence. Rowe concludes cautiously that "perhaps three weeks of immobilisation may be sufficient time for healing to occur". Here it will only be stated that in the present series, as in most previous reports, this period was as a rule much shorter. Grounds undoubtedly exist for testing a fixation of arm to trunk (sling and swathe) over a period of 3 weeks in a large series of primary dislocations in younger patients.

With respect to the results, it may first be stated that the incidence of recurrence in this series was less than 1 per cent, a result which is equal to or more favourable than the best reported by Bankart's and Putti-Platt's methods and clearly superior to those achieved by other methods (possibly with the exception of Gallie's very complicated method). Previous information in the literature (*Thomasen* and others) that Eden-Hybbinette's operation was a satisfactory method from this point of view can therefore be confirmed. The mechanisms which decide the curative effect are not completely known but probably they are mainly dependent on an anterior scar formation fastening the capsule to the rim *and leading to a certain shrinking of the capsule* and shortening of the subscapularis tendon. Extra-articular interventions, of which there were a great number of variants at the beginning of the century, *proved* to be unreliable as a rule. Such interventions

nette's operation seems to be a satisfactory method giving a low incidence of recurrence and good functional end results. Certain facts favour the argument that the operation increases the risk of arthrosis arising in the humero-scapular joint. If this is really the case, however, it does not probably constitute a basic disadvantage to the method when the good clinical results which do not deteriorate with long observation are taken into consideration.

RESUME

120 epaules ont subi l'operation Eden-Hybbinette pour recidive de dislocation anterieure de l'articulation humero-scapulaire. Un rapport detaillé est fourni concernant l'age de la première dislocation, le trauma initial, l'immobilisation lors de la première dislocation, la duree de l'anamnèse et le nombre des dislocations. Pour 114 epaules il a ete fait l'estimation du resultat clinique final entre 2 et 17 ans et demi après l'operation. La periode moyenne d'observation a ete de 8.5 ans. 86 pour cent des cas ont ete consideres comme excellents ou bons, 11 pour cent comme satisfaisants et 3 pour cent seulement comme non satisfaisants.

105 malades ont ete examines aux rayons X a l'occasion d'examens cliniques complementaires, les deux epaules etant presentees dans trois projections. Cet examen a revele l'existence d'arthrose moderee ou grave dans l'articulation humero-scapulaire dans 70 pour cent des epaules operees, alors que dans les epaules non disloquees l'incidence n'est que de 7 pour cent approximativement.

Independamment du facteur etiologique qui domine, l'operation Eden-Hybbinette semble etre une methode satisfaisante avec laquelle le taux de recidive a ete tres bas et les résultats fonctionnels finaux bons.

ZUSAMMENFASSUNG

120 Schultergelenke wurden mittels Eden-*Hybbinette*-Operation wegen Verrenkung nach vorne behandelt. Ein ausfuhrlicher Bericht hinsichtlich des Alters bei der ersten Verrenkung, des ersten Traumas, der Ruhigstellung nach der ersten Verrenkung, der Länge der Vorgeschichte und der Anzahl der Luxationen wird gegeben. Bei 114 Schultern wurde das klinische Endergebnis 2 bis 17.5 Jahre nach der Operation beurteilt. Die durchschnittliche Beobachtungszeit war 8.5 Jahre. 86 prozent der Falle wurden als ausgezeichnet oder gut angesehen, 11

of comparable series operated on according to other methods has been encountered in the literature.[1]

It is well known that arthrosis in the humero-scapular joint often does not produce symptoms and De Palma declares that a certain degree of arthrosis almost always occurs after 40 years of age. In this series it was also established that the connection between clinical symptoms and arthrosis upon the whole was slight and *that freedom from* symptoms often existed even with severe arthrosis.

SUMMARY

120 shoulders were treated by Eden-Hybbinette's *operation for recurrent* anterior dislocation of the humero-scapular joint. A detailed report is given concerning age at the 1st dislocation, initial trauma, immobilisation at the 1st dislocation, length of the anamnesis and the number of dislocations. For 114 shoulders (= 95 per cent of the whole series) the clinical end result was evaluated *2* to 17.5 years after the operation. The average observation period was 8.5 years. The results were classified with regard to subjective symptoms, ability to work and range of movement. 86 per cent of the cases were evaluated as excellent or good, 11 per cent as satisfactory and 3 per cent as unsatisfactory. One recurrence appeared and this was successfully treated by renewed operation according to the same method.

105 patients (106 of the shoulders operated on in the series) were X-rayed in association with the clinical follow-up and both shoulders were presented in three projections. This revealed the existence of moderate or severe arthrosis in the humero-scapular joint in fully 70 per cent of the shoulders operated while the incidence among non-dislocated shoulders was approx. 7 *per cent*. The presence of such arthrosis *increased with more than* [illegible] *years observation* and *more than* 10 dislocations.

Etiological factors are discussed as well as the incidence of recurrence and the clinical end results in relation to other methods.

Independently of whichever etiologic factor dominates, Eden-Hybbi-

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[1] In 1949 Jakobson reported a modification of the Eden-Hybbinette method introduced in 1937 at the Orthopaedic Clinic of Karolinska Institutet. In this the transplant is not hooked up onto the glenoid margin but its lateral rounded part extends to and builds out the anterior glenoid rim level with it. The modification was designed on the assumption that the risk of postoperative arthrosis deformans would be diminished if conflict was avoided between the transplant and the humeral head.

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ANTERIOR RECURRENT DISLOCATION OF SHOULDER

By

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The current concept of the causes of the anterior recurrent dislocation of the shoulder is Bankart s lesion and/or elongation and consequent weakness of the tendon of the key muscle subscapularis produced by trauma of the first episode Operating surgeons of the British Common wealth of Nations and North American countries will agree that Bankart s lesion is not found in operations in a good number of cases nor can elongation of the tendon of subscapularis be substantiated by direct observation The chances of post operative recurrence of Putti Platt and Bankart s operations are considerably high according to some surgeons Osmond Clarke has treated "50 60 cases of post operative recurrence done by others in his series of 200-250 cases Moreover there is always an alteration to scapulo humeral rhythm limitation of external rotation and abduction of the gleno humeral joint however small In our experience this limitation of overhead elevation is masked by excessive mobility of the scapula compared with that of the sound side even in those with the best results

Continental surgeons especially in Germany and Scandinavian countries do not share the above view They treat their cases by extending the anterior margin of the glenoid by Eden Hybbinette operation or similar procedures They get practically no post operative disability and the chance of recurrence is extremely rare (*Friberg* 0 66 per cent *Lange* none in his series of about *300 cases*)

None too low incidence of spontaneous recurrent dislocation and unequivocal excellent results (full abduction and external rotation) in 45 cases including three epileptics in a period of ten years of treatment of anterior recurrent *dislocation* by posterior transfer of latissimus dorsi and recent good results of treatment by rotation osteotomy of the humerus have raised doubt about the accepted causes of recurrence

This article is *written to* exploit the new concepts of the shoulder

prozent als befriedigend und 3 prozent als unbefriedigend. 105 Patienten wurden im Zusammenhang mit der Nachuntersuchung Röntgen untersucht und beide Schultern wurden in drei Projektionen dargestellt. Dies zeigte das Vorhandensein von moderater bis schwerer Arthrose im Schultergelenk bei vollen 70 prozent der operierten Schultern auf, während die Häufigkeit bei den nicht luxierten Schultern ungefähr 7 prozent war.

Unabhängig davon welcher ätiologische Faktor vorherrscht, scheint die Eden-Hybbinette Operation eine zufriedenstellende Methode zu sein, da sie ein seltenes Entstehen von Rückfällen und gute funktionelle Endresultate ergibt.

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Figure 2 Illustration of the scapula showing the retro tilt of the glenoid in relation to its axis This is present in the majority of cases

three types (Figure 1) In A & B types the humeral head has contact with a good portion of the articular surface of the glenoid in all positions during movement of the gleno humeral joint This helps the head to stay in the glenoid cavity

2 *Tilt of the Glenoid*

This has been studied in macerated specimens by anthropometry and in the living by radiological examination (Figure 2) The latter group included cases of recurrent anterior dislocation either before or after treatment The majority of normals had a varying degree of posterior tilt of the glenoid In a small group of normal individuals and in all cases of anterior recurrent dislocations studied the glenoid tilt was found to be reversed *i e* was an anterior tilt Obviously the posterior tilt of the glenoid helps to check the tendency to anterior subluxation

3 *Role of Subscapularis Infraspinatus and Teres Minor*

During abduction electromyography (Figure 3) shows that the power of the subscapularis rises from 120 to its maximum at 150 where from it shows a quick and steady fall Obviously its power is utilised to roll the head of the humerus posteriorly a movement which coun

mechanism in order to establish the aetiology of anterior recurrent dislocation of the shoulder and to outline all possible methods of treatment including posterior transfer of latissimus dorsi. This method of latissimus dorsi transfer was introduced first in 1956 by the author and quoted in the Hunterian lecture of the Royal College of Surgeons of England in 1957.

ANATOMICAL AND PHYSIOLOGICAL CONSIDERATIONS OF THE MECHANISM OF ANTERIOR DISLOCATION

Clinically and radiologically it has been found that most of the head of the humerus projects beyond the anterior glenoid rim when the limb is elevated to the vertical. This spontaneous tendency to subluxation due to the projection of the humeral head starts as the limb is elevated beyond 60° in the scapular plane. It increases with further elevation and especially when it is carried in planes behind the scapular plane. This is inevitable due to normal retrotorsion of the head of the humerus which changes into relative antetorsion with vertical elevation. Reduced retrotorsion of the upper end of the humerus diminishes this tendency. Nature attempts to stem this inherent instability by:

1. *Relative Contour of the Head of Humerus and Glenoid Cavity*

Studies on the radii of curvatures of the head of the humerus and the glenoid cavity made possible the classification of this joint into

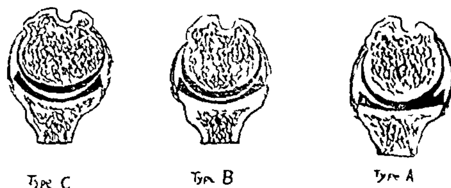


Figure 1. Shows diagrammatically the three types of joint. In type [illegible] joint the head of the humerus [illegible] on the margin of the glenoid cavity and labrum in all positions of movement of the glenohumeral joint. (Saha, A. K.: Theory of Shoulder Mechanism—Descriptive and Applied. Springfield, Ill., Charles C Thomas, Publisher, 1961. Reproduced by courtesy of Publisher.)

PREDISPOSING FACTORS

In type C joint the head of the humerus rides on the glenoid margin and labrum in all positions of movement the radius of the head being greater than that of the glenoid cavity During abduction all the stress would naturally fall on the anterior hemi ring of the glenoid labrum with its maximum effect at this centre If the attachment of the labrum is strong the head of the humerus will jump off it and dislocate through a rent in the neighbouring capsule In those cases where the attachment is weak the glenoid labrum will be shorn off the bony margin for a varying segment depending on the force and degree of abduction (Bankart s lesion) Whether the labrum is detached or not during the first episode it is liable to secondary detachment attenuation and fibrillation with repeated dislocations Rarely the glenoid labrum may not develop and form as it were only a thickened part of the capsule near its attachment In these cases the recurrent dislocation occurs at a very young age

2 Increased retrotorsion of the upper end of the humerus may also be a factor in causing anterior recurrent dislocation

3 Reduced retrotilt or anterior tilt of the glenoid may fail to give protection to head as the limb is raised to the vertical

4 The power of subscapularis infraspinatus and teres minor may be inadequate due to congenital weakness paralysis (poliomyelitis) and elongation (vide supra) and consequent slackness and weakness from previous trauma

In spontaneous anterior recurrent dislocation the first attack occurs without any trauma while putting the hand into a coat sleeve behind the head during sleep bowling in cricket raising the arm for an over arm stroke in a tennis game etc Such patients are usually in the late second or third decade of age

In poliomyelitis with paralysis of either subscapularis or infraspinatus or both there is anterior subluxation of the head of the humerus which increases with attempt to raise the arm overhead

Thus the cases of anterior recurrent/habitual dislocation belong to one of the three groups (1) Post traumatic (2) spontaneous and (3) paralytic The term habitual dislocation has been exclusively used for paralytic cases These cases are perpetually subluxated or dislocated and are painless These can be put back in the socket at ease passively In a particular case one or more of the above mentioned predisposing factors may be present

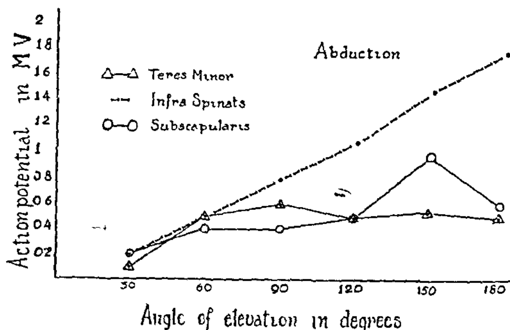


Figure 3. Composite graphical representation of action potential of teres minor, infraspinatus and subscapularis in millivolts during abduction of shoulder in a normal adult. The abscissa represents the angle of elevation in degrees and the ordinate action potential in millivolts. (Saha, A. K.: Theory of Shoulder Mechanism—Descriptive and Applied. Springfield, Ill., Charles C Thomas, Publisher, 1961. Reproduced by courtesy of Publisher.)

teracts the tendency to anterior subluxation. The decline of power of the subscapularis between 150°–180° of elevation at a crucial stage when the relative antetorsion of the upper end of the humerus is taken over by the infraspinatus whose power steadily rises and is maximal at 180°. Though the insertion of infraspinatus is at the posterosuperior surface of the greater tuberosity yet the posterior rolling occurs owing to relative maximum antetorsion of the upper end of the humerus and change of mechanical axis when it reaches the vertical overhead position. Teres minor shows a plateau curve from 60° to 180° and probably is a synergist to infraspinatus and subscapularis.

The above mentioned factors preventing tendency to anterior subluxation of the head of the humerus during its critical phase of abduction in different planes may not however be adequate. This particularly occurs if the force of abduction is sudden and severe. The anatomico-physiological deviations from the normal enumerated below add to this. Without the predisposing factors the dislocation heals after reduction and recurrences are unlikely.

3 *Enhancement of the Subscapularis Power*

The power of subscapularis may be reinforced by a muscle transfer These muscles should have similar direction of fibres as that of the subscapularis and their rerouting should be possible to the lesser tuberosity without disturbing the nerve and vascular supply The pectoralis minor and upper two digitations of serratus anterior have been used in habitual paralytic dislocation in flail shoulder These not only restore the horizontal steerer but also cure the subluxation These are not suitable in post traumatic and spontaneous cases of anterior recurrent dislocation owing to technical difficulties due to presence of normal pectoralis major deltoid trapezius and levator scapulae

4 *Enhancement of Power of Infra Spinatus et Teres Minor*

This has been done with the help of the posterior transfer of the latissimus dorsi to the small tubercle at the lowest posterior limit of greater tuberosity a point which marks the junction of aponeurotic and comparatively fleshy fibres of teres minor When latissimus dorsi is the only muscle for rerouting as a horizontal steerer in the treatment of paralytic flail shoulder it has been found that the habitual dislocation is also cured

This is the only operation suitable for paralytic post traumatic and spontaneous cases The procedure is described (vide infra) with a report of 45 cases of spontaneous and post traumatic anterior recurrent dislocation

MATERIALS

45 consecutive non paralytic cases of anterior recurrent dislocation of shoulder over period of 10 years till the end of 196 are reported These include 4 cases of Prof C K *Chaudhur* FRCSF 3 of Dr A K *Das* FRCS FRCSE and 3 of Dr A *Sengupta* FRCS and are tabulated below

The three cases with bilateral anterior recurrent dislocation were epileptic This was controlled before the operative treatment

Five of the forty five cases were spontaneous dislocation in two of these the first episode happened while throwing a ball one in his left shoulder during a forward drive of a full toss ball in cricket one while raising his hand to strike a dog and lastly one with no relevant history

31 cases had more than 10 recurrences *Eight of these did not require doctor s help* during reduction and had innumerable episodes They could dislocate as easily as they could reduce the dislocation on their own They had no pain during a slip and the joints were lax particularly while carrying moderate weights They came for treatment because of their inability to *perform* normal manual labour requiring raising and carrying loads One patient a shopkeeper could not lift the balance while weighing merchandise for his customer

THEORETICAL BASIS OF THE POSSIBLE METHODS OF TREATMENT OF ANTERIOR RECURRENT DISLOCATION OF THE SHOULDER AND ITS CHOICE IN A PARTICULAR CASE

Neither the block nor the check operations by muscle, tendon and fascia nor repair of Bankart's lesion would remove the cause of recurrence. The causes of recurrence are removed by one or more of the following procedures.

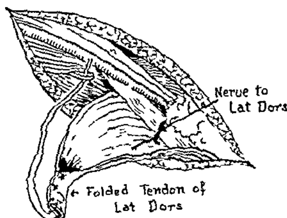
1 *Restoration of the Glenoid Retrotilt by Bone grafting or Osteotomy*

Eden Hybbinette operation is the nearest rational procedure in practice. It indirectly restores the tilt of the glenoid and enlarges its gliding surface for the head of the humerus. Treatment by simple osteotomy of the neck of the scapula to increase the retrotilt of glenoid when it is well developed would similarly effect a cure. In the presence of an aplastic glenoid which however is extremely rare, Eden Hybbinette operation is choice. The method may have to be performed in extremely rare instances of persistent post operative apprehension and recurrence after other operations and especially in the presence of severe anterior tilt of the glenoid.

2 *Prevention of Undue Anterior Projection of Head of Humerus beyond the Glenoid Margin with Overhead Elevation of the Arm*

Excessive anterior projection of the head of the humerus with vertical elevation may be prevented by limitation of external rotation of the arm or by reduction of retrotorsion of upper end of humerus. The former is done by Putti Platt and Magnuson Stack operations. Due to altered mechanism after these operations limitation of the vertical elevation however small always occurs. This is masked by the hypermobility of the scapula in the best of results. A rise in power of the subscapularis from shortening its elongated tendon is not justified as it lacks proof.

Alternatively rotation osteotomy of the upper end of humerus (Saha Das) will reduce the undue projection (relative antetorsion effect) with the elevation of the arm to the vertical. The operation is extra articular and does not restrict the movements of the gleno humeral joint in any direction. This has been successfully tried in anterior recurrent dislocation in non paralytic cases. The long term results are however still awaited.



Figur 4 Shows the letached latissimus dorsi tendon folde l longitudinally by inter rupted silk sutures 4 transfixation suture of stout silk is seen passing through its en l for rerouting It long free ends a e held in a haem stat ready for withdrawal b tween the long head of t iceps and deltoi l

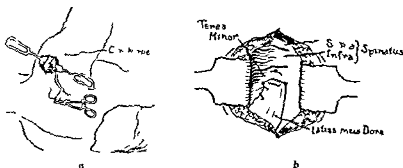


Figure 5 a Shows the upper end of the humerus through the split mus le fibres and fascia beneath tl e d ltoid The incis on is above the course of the circumflex nerve in dotted l n The latissimus dorsi tendon s seen withdrawn in th depth of wound Figur 5 b D agram show ng latissimus dorsi after za ron to the peri isteo apo neu ot c pocket at the poste ior l u er l mit of the gre ter tuberosity of the humerus

folded on itself for reducing its width by interrupted silk sutures The folded tendon is tr nsf xe l by a mattress sutures (4 chinese silk) with the free ends projecting from the cut surf ce of the ten lon and ready for rerouting (Figure 4)

The posterior border of the deltoid is dev l ed and freed from triceps By finger di se t on a tunnel is made from about the centre of its posterior bor ler towards the h d of the humerus keeping deep to the fascial covering of the deltoid No sharp instrument should be used to avoid injury to the b anches of the circumflex and radial nerves

The others came because of complete helplessness and severe pain during dislocation and their inability to take part in games and normal activities of life due to apprehension

Table 1

Year	Number	Male	Female	Side	Remarks
1956	1		1	Bilateral	Patient epileptic
1957					
1958	4	4		2 right 2 left	
1959	5	5		3 right 2 left	One case developed epilepsy in 1962
1960	4	3	1	3 right 1 left	One spontaneous on the right side while throwing a ball
1961	8	8		7 right 1 left	Two spontaneous in one case while trying to hit a dog and during normal activity in the other
1962	7	7		5 right 2 left	
1963	5	5		4 right 1 bilateral	Bilateral case was epileptic
1964	3	3		3 right	One spontaneous while throwing a ball
1965	8	8		6 right 1 left 1 bilateral	Left one was spontaneous during forward drive of a full toss ball in cricket The bilateral case was epileptic

METHOD OF POSTERIOR TRANSFER OF LATISSIMUS DORSI

Under general anaesthesia the patient is tilted by sand bags and adhesive strapping to 45 degrees to the opposite side The extremity is draped from below to the lower third of the arm and is held and controlled by an assistant during the operation With the arm abducted to 120 and externally rotated an incision 6 7 inches in length is made passing through the junction of the anterior 1/3 and posterior 2/3 of the outer wall of the axilla and parallel to the posterior axillary fold After incising the axillary fascia the belly of the latissimus dorsi is exposed its flat tendinous insertion is dissected free from the underlying muscle teres major retracting the neurovascular bundle with the radial nerve disappearing beneath the outer border of the long head of the triceps The tendon is blended with the teres major and has to be separated with a sharp knife The tendon thus freed is severed close to its insertion and is



Figure 6 PCS operated in October 1958 shows the functional status of the left shoulder in December 19 5 This case classified earlier as good in 196? n u comparable full range of all movements on either side Prominence of both scapulea lenotes the limit of internal rotat on







normal activity including all types of games swimming and wrestling Different surgical groups including visitors from other countries could not correctly identify the side of operation on clinical examination in these cases when lightly dressed

2 *Good* – Painless just clinically discernible restriction of rotation in one or both directions (10 per cent or less) normal scapulo humeral rhythm with elevation no recurrence and normal activity including all games as in 1 (Figure 6)

3 *Fair* – Occasionally painful restriction of rotation by over 10 per cent but below 50 per cent no recurrence and slight disturbance of scapulo humeral rhythm though the vertical elevation is full Normal activity including all games as in 1

4 *Poor* – Painful gross restriction of movements head of the humerus may not be in the socket activities restricted to a varying degree

45 cases including three epileptics with bilateral affection were operated on during last ten years from 1956–1965 The first of the three epileptics had Banker s operation on the right in 1955 i e a year be

The assistant now adducts flexes and rotates the arm internally on the chest An incision (2") is made vertically downwards from the acromion just in front of its sharp posterior angle The incision is carried through the fibres of the deltoid and through its deep fascia The top of the greater tuberosity and adjoining shaft of the humerus is exposed (Figure 5) by retracting the cut edges of the muscle and its fascia on its deep surface The tendon of latissimus dorsi with the transfixation sutures is drawn to this wound through the interval between the deltoid and the long head of triceps The tubercle marking the postero inferior limit of the greater tuberosity is identified A small transverse incision is made on the shaft immediately below it and a pocket is made by raising the upper flap from the bone with the help of a rougine The latissimus dorsi tendon with its transfixation suture is drawn through this fascio periosteal pocket and fixed to the under surface of this upper flap by mattress suture The edges of the flaps are now fixed to the tendon by interrupted silk sutures All sutures are tied with the shoulder held in the zero position to relax the latissimus dorsi Wounds are closed and subsequently a thoraco brachial plaster spica is applied with the limb in the scapular plane abducted to 90 elbow flexed and hand at the level of the mouth Special care is taken to check the position Deviation of the head is likely to occur if the humerus is not kept strictly in the scapular plane with consequent post operative subluxation and fixation of the head in the new position

Post operative Management and Complications

The shoulder spica renewed after removal of the sutures on the 10th day is kept for 4–5 weeks Rehabilitation exercises are given for recovery of function None of my patients had any guidance from an organised physiotherapy and rehabilitation centre Complete recovery of function followed the shortest within a period of 3 weeks and the longest in about 10 weeks

The complications of the operation were confined to the first ten cases All of them were immobilised in zero position a postition which was later found to require utmost care in follow up by skiagraphs Even the slightest deviation of the limb from the scapular plane may cause anterior subluxation This happened in two of my cases and remained unnoticed during the period of immobilisation They have been graded as poor after subsequent management

Recently we have started immoblising the limb either hanging or in 90 abduction (vide supra) Post operative functional recovery time is longest in the hanging group intermediate in the group treated in 90 abduction and minimum in those treated in the zero position

Other complications encountered were transient palsy of radial nerve in one case paresis of the posterior fibres of deltoid in one and occasional pain in four Scrupulous adherence to technique is the best prevention apart from the last mentioned complication

RESULTS

Results were classified under four headings

1 *Excellent* – Painless full range of movements scapulo humeral rhythm comparable with the sound side (with elevation) no recurrence

without radiological check up was responsible They required surgery to make them reasonably fit for work It will be seen that not a single case came under the grade fair The very few best results of personal cases of Bankart s and Putti Platt operations done before 1956 satisfied the criteria of fair results in this table

Two of these cases with right sided anterior recurrent dislocation graded as excellent complained of occasional apprehension during games and wrestling They required firm reassurance One of them is at present a combatant army officer and the other a covenanted officer in a British firm Both of them engage in all types of games and swimming and the army officer in wrestling as well One case who had epileptic fits three years after the operation had apprehension several times and is now fully cured both of epilepsy and apprehension

SUMMARY

There is no single constant pathologic anatomical change in anterior recurrent dislocation of the shoulder which could be attributable as the cause of recurrence The changes are the effects rather than the cause

The aetiology of anterior recurrent dislocation has been described on the basis of the newer concepts of the shoulder mechanism The mechanism of dislocation in paralytic post traumatic and spontaneous cases is dependent on the predominance of one or more of the causes responsible for the recurrence

45 consecutive cases of post traumatic and spontaneous anterior recurrent dislocation treated by posterior transfer of latissimus dorsi over a period of ten years are reported 35 cases show excellent 8 good and 2 poor results None of them had recurrence

RESUME

Il n y a pas une seule modification anatomique pathologique constante dans la dislocation anterieure recidivante de l epaule qui puisse etre attribuée a une cause recidivante Les modifications sont plutot des effets que des causes

L etiologie de la dislocation anterieure recidivante a éte decrite sur la base de conceptions nouvelles du mécanisme de l epaule Le mecanisme de la dislocation dans les cas paralytiques post traumatiques et spontanés depend de la prédominance de l une ou l autre des causes responsables de la récidive

Table 2

Year of operation	Excellent	Good	Fair	Poor	Total	Remarks
1956	1				1	No pain and recurrence in the left shoulder Recurrence in right shoulder dislocates during epileptic seizure
1957						
1958	2			2	4	*The poor results were due to dis*location of the humeral head during post operative immobilisation They had secondary operations for functional recovery
1959	5				5	One case developed epileptic fits three years after operation since controlled but has no recurrence *He* had apprehension several times
1960	2	2			4	Apprehension thrice during wrestling after the operation *He needed reassurance before he* joined the army
1961	5	3			8	One case had *apprehension twice* shortly after operation though he now engages in all types of games including fast bowling golf and swimming without recurrence or apprehension
1962	6	1			7	
1963	5				5	The epileptic case had only operation on the left side
1964	2	1			3	
1965	7	1			8	The epileptic case had operation on the left side

fore the latissimus dorsi transfer on the left The other two had operations only on the left the worse of the two sides All the cases were followed up till the end of 1965 when 35 cases were excellent 8 good and 2 poor The two cases of poor results were the second and the fifth of the series Faulty post operative management in the zero position

10 Hustinx L. (1926) Transplantation of pectoralis major muscle in substitution for deltoid muscle or in active strengthening of shoulder joint in habitual dislocation *Ned T Geneesk* 1 1262

11 Hyllinette S (1932) De la transplantation d un fragment osseux pour remedier aux luxations recidivantes de l epaule constatations et resultats operatoires *Acta chir scand* 71 411

12 Jen J (19 0) Role of subscapularis muscle in stability of shoulder joint Magnuson operation *Med J Austr* 1 478

13 Lange M (1961) Personal communication

14 Lenormant C. (1931) Treatment of recurrent dislocation of shoulder by formation of bony barrier *French Med Rev* 1 21

15 Magnuson P B & Stack J K (1943) Recurrent dislocation of shoulder *J Amer med Ann* 123 889

16 Merle d Aubigne R Cauchois J & Alkaley I (1951) Therapy of recurring luxation of shoulder *Rev Chir Orthop* 37 119

17 Mosley H F (1936) Recurrent dislocation of shoulder *Proc r Soc Med* 9 2 ?

18 Narasimham N S (194) Recurrent dislocation of shoulder joint *Indian J Surg* 7 193

19 Newton A H (1936) Shoulder dislocation during sleep *Brit med J* 2 1117

20 Nicola T (1929) Recurrent anterior dislocation of the shoulder new operation *J B ne Jt Surg* 11 128

21 O Connor D S (1931) Recurrent subluxation of head of humerus from muscular atrophy *U.S Nav M Bull* 29 673

22 Osmond Clarke H (1948) Habitual dislocation of the shoulder Putti Platt operation *J Bone Jt Surg* 30 B 19

23 Osmond Clarke H (196) Personal communication

24 Oudard P (1946) Treatment of recurrent luxation of shoulder by means of bony abutment *Rev Med Nav* 1 305

2 Saha A K (1958) Zero position of the gleno humeral joint Its recognition and clinical importance *Ann roy Coll Surg Engl* 22 223

6 Saha A K (1961) Theory of Shoulder Mechanism Descriptive and Applied Charles C. Thomas Ill U S A

27 Saha A K (1963) Anterior recurrent dislocation of the shoulder *J ur Int Coll Surg* 39 361

28 Saha A K (1967) Surgery of the Paralysed and Flail Shoulder *Acta orthop scand* Suppl 97

29 Speed K (1927) Recurrent anterior dislocation at shoulder operative cure by bone graft *Surg Gynec Obstet* 44 468

Il est rapporte 45 cas consecutifs d une dislocation anterieure recidivante post-traumatique ou spontanee traites par transfert posterieur du grand sorsal au cours d une periode de dix ans 35 cas ont donne d excellents resultats 8 de bons resultats et 2 des resultats mediocres Il n y a pas eu de recidive

ZUSAMMENFASSUNG

Es gibt keine konstanten pathologisch anatomischen Veränderungen die als Grundlage der Dislocatio humeroscapularis anterior habitualis angeführt werden können Die anatomischen Veränderungen sind eher als Folge und nicht als Ursache der Dislocation zu bezeichnen

Die Aetiologie der Verrenkung wird vom Verfasser auf der Basis einer neuen Konzeption des Mechanismus des Schultergelenkes beurteilt Der Verrenkungsmechanismus der paralytischen der posttraumatischen und der spontan auftretenden Verrenkungen ist vom Vorhandensein einer oder mehrerer Ursachen abhängig

45 Fälle von posttraumatischen sowie spontan auftretenden Verrenkungen wurden während einer 10 jährigen Epoche durch hintere Transplantation des Musculus latissimus dorsi behandelt In 35 Fällen waren die Ergebnisse ausgezeichnet in 8 Fällen gut und in 2 Fällen schlecht Keine Rückfälle wurden beobachtet

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Acta orthop. scandinav. 38, 494–500, 1967

From Pori General Hospital (Head: Professor Aulis Korhonen, M.D., deceased),
Pori, Finland

TREATMENT OF "MALLET FINGER" DEFORMITY BY MEANS OF SKIN STRIP

By

PEKKA NUMMI

Received 2[illegible].XI.66

Rupture of the extensor tendon of the terminal phalanx of the finger is a common complaint and often awkward to treat. The tendon tissue here is thin, so it may be easily ruptured even by a small trauma. The rupture may be subcutaneous, and the dorsal corner of the terminal phalanx is often fissured together with tendon tissue. The rupture may also frequently occur in connection with a wound or laceration. The rupture results in a so called mallet finger deformity.

A fresh subcutaneous rupture is usually treated conservatively with immobilization. Since the hand must be washed and is in partial use, immobilization with plaster of paris often fails. The plaster when moistened becomes soft and loses its efficiency. This has resulted in the construction of various metal splints (e.g. *Winterstein* 1951). Despite all efforts the results achieved by conservative therapy are only relatively good. *Hallberg & Lindholm* (1960) for example presented a series of 107 patients treated conservatively and followed up: an extension defect of over 20 degrees remained in 53 of these cases, while another 22 continuously suffered some degree of pain.

Pratt, Bunnell & Howard (1957) described internal fixation with percutaneous drilling, a method in which a Kirschner wire drilled percutaneously through the terminal and the basal phalanges acts as an internal splint. *Bohler* (1953) described a fixation with two wires drilled crosswise through the terminal phalangeal joint.

A rupture accompanying a cut can be treated when the wound is being closed, for example with a percutaneous so called figure of eight suture using metal wire (*Moberg* 1956).

In cases in which conservative treatment has failed or the injury

has been neglected for a long time surgery is necessary One method is the fixation of the extensor tendon as described by *Bunnell* (1944) the loose end of the tendon is fixed with a pull out wire suture at its point of insertion *Nichols* (1951) proposed reconstruction with the aid of a graft taken from the palmaris longus tendon

Since the operative methods of treatment are relatively laborious the present author used simple reconstruction with the aid of whole thickness skin strip for the treatment of the "mallet finger deformity The use of skin in tendon repairs has long been known For example *Loewe* (1913) replaced the defect of the extensor tendon of the thumb with a strip of skin from which the epidermis had been scraped off Having used skin for the plastics of inguinal hernia he found that a tissue specimen taken from it later showed metaplasia The sweat and sebaceous glands peculiar to the skin disappeared while the elastic fibres were well preserved A similar finding was made by *Rehn* (1919) who studied graft changes also by animal experiments Subsequently skin has been increasingly used in tendon reconstruction as stated *e g* by *Brandis* (1941) Earlier the epidermis was removed but whole thickness skin was later introduced Its usefulness and the metaplasia occurring in it have been studied in animal experiments *e g* by *Kivilaakso* (1955) and *Jokinen* (1958) The former found that the skin graft gradually became similar to the original tendon tissue *Jokinen* found in her studies that a tendon replaced with skin was equal after one year to normal tendon tissue in tensile strength

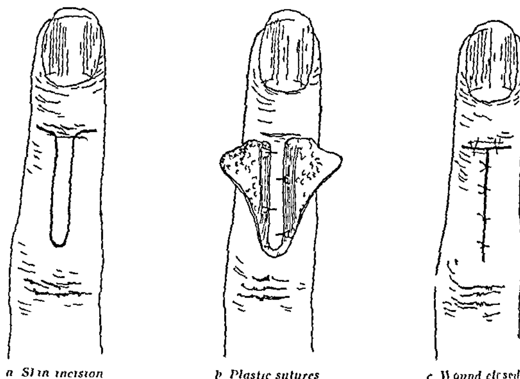
Whole thickness skin was used in the reconstruction of the extensor tendon of the terminal phalanx described below

MATERIAL

The c e of pat ents derived from Po i General Hospital during 1957–65 All types of cases reg rdless of *the type of injury* involved were treated as can be seen from the attached table One of the patients wa female the othe s male Six were under 15 ea s of age the balance were adults and the oldest was 51 The fingers affected were 4 to efinge 6 middle fingers 8 ring fingers nd 1 l ttle *finger*

METHOD OF TREATMENT

Th techniqu we e as follows a T incisi n was made in the skin (Figure 1 a) The trip cf kin remaine l attached at the d stal part of the f nger The strip must be a m nimum of 2 mm wide The skin at the sides of the finge was detached from its b e a sufficiently w de a ea so that on closing the margins extended across



a Skin incision *b Plastic sutures* *c Wound closed*

Figure 1

the strip of skin The strip of skin was sutured with the terminal phalanx over extended to the proximal aponeurosis with 4–5 merselen sutures (Figure 1 b) The wound was closed so as to cover the strip of skin (Figure 1 c) The finger was immobilized *with the terminal phalanx overextended by means of a metal or plaster* of paris splint for 3–5 weeks (see Table 1)

All the patients were treated at the outpatient clinic and prophylactically they were given penicillin or some other antibiotic

RESULTS OF TREATMENT

All the patients were followed up and the results presented are late findings The periods of observation ranged from 6 months to 8 years

The table gives the therapeutical result as related to the type of injury and the date by which treatment started

In all cases of subcutaneous rupture the therapeutical result was good although many were treated weeks after the injury Figure 2 gives an example of the result

Ruptures accompanying a cut were treated in the secondary phase after the wound had healed and the result was good in all of them

There were 6 ruptures accompanied by lacerated bruises the result

Table 1 Cases Treated with Skin Plastics and Results of Treatment

		No	Immobilization weeks	Suppuration of suture ended weeks after operation	Result of treatment
Subcutaneous rupture	Skin plastics within 2 weeks of injury	4	3 6	4–7	good
	No primary treatment skin plastics within 3 4 weeks of injury	2	3 5	4 8	good
	Primary plaster of paris immobilization skin plastics within 6–7 weeks of injury	3	3 5	0–4	good
Rupture and cut	No primary treatment skin plastics within 3 6 weeks of injury	3	3–4	4–12	good
	No primary treatment skin plastics within 11 weeks of injury	1	4	0	good
Rupture and lacerated bruise	No primary treatment skin plastics within 4 weeks of injury	1	3	[illegible]	good
	No primary treatment skin plastics within 7 weeks of injury transverse fracture of terminal phalanx	1	5	3	good
	No primary treatment skin plastics within 3 weeks of injury	1	4	4	fair
	No primary treatment skin plastics within 10 21 weeks of injury	2	3 4	6	fair
	No primary treatment skin plastics within 11 weeks of injury transverse fracture of middle phalanx	1	4	4	poor
	Total	19			

Results of treatment

good = extension deficit less than 5 flexion deficit less than 10
fair = extension deficit less than 3

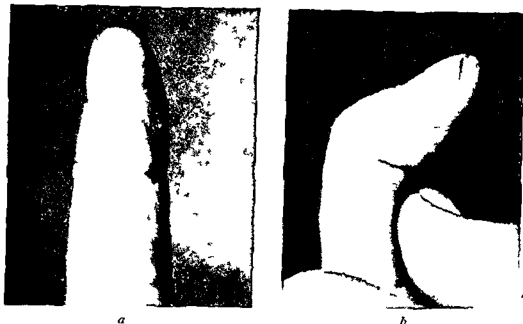


Figure 2. Male patient aged 33 years. Subcutaneous rupture of the extensor tendon of the terminal phalanx of the middle finger of right hand photographed [illegible] years after treatment. a extension, b flexion.

was good in only 2. In 3 cases the result was inconclusive, while one, a case of open comminuted fracture of the terminal phalanx, showed no improvement.

A complication was infection of the wound in the late phase. The infection was always superficial. Sutures used in the skin plastics were *removed as they became visible. The dates when the suppuration ended* are given in the table.

DISCUSSION

A review of the therapeutical results shows that the method of treatment described provides a good result in subcutaneous rupture regardless of the lapse of time from injury to treatment. The same applied to the treatment of old ruptures associated with a cut. In complicated cases of *lacerated bruise improvement is possible if the passive function* of the joint is intact and no important scarring is present in the dorsal skin of the middle phalanx or in the aponeurosis. The infection of the wound is understandable as the plastics form as it were a skin pocket. The therapeutical result did not suffer from the infections. It is therefore difficult to say which affects the improvement more in this treatment, the support which the skin strip provides and the metaplasia

that occurs in the skin strip or the cicatricial tissue formed by infection

No cyst formation or disfiguring scars were noted

SUMMARY

The author describes a method of treating a ruptured extensor tendon of the terminal phalanx of the finger A strip is taken from the dorsal skin of the finger so that its distal end remains attached at the terminal phalanx The strip of skin is sutured to the proximal aponeurosis using mercelen sutures The skin detached from its base along the sides of the finger is sutured on top of the strip The finger is immobilized for 3–5 weeks The sutures caused superficial infection in almost all the cases but this did not impair the therapeutical result The tendon healed well in all simple subcutaneous ruptures and in ruptures accompanying a wound despite the fact that the majority were not treated until over 3 weeks after the injury In cases with lacerated bruises the result was inconclusive

RESUME

L auteur decrit une methode de traitement de la rupture du tendon extenseur de la phalange terminale du doigt Un lambeau de la peau dorsale du doigt est preleve de maniere que son extremite distale reste attachee a la phalange terminale Le lambeau de peau est reuni a l aponévrose proximale par sutures mercelenes La peau detachee de sa base le long du doigt est suturee sur le sommet du lambeau Le doigt est immobilise pendant 3 a 5 semaines Les sutures provoquent une infection superficielle dans pratiquement tous les cas mais cela ne nuit pas au resultat therapeutique Le tendon se guerit bien dans tous les cas de rupture sous cutanee simple et dans les ruptures qui accompagnent une blessure malgre le fait que la majorite des cas n ont pas ete mis en traitement immediatement mais qu il s est parfois ecoule plus de trois semaines apres la lesion Dans les cas de contusions lacerees le resultat n a pas ete concluant

ZUSAMMENFASSUNG

Der Verfasser beschreibt eine Methode zur Behandlung der zerrissenen Streckschne der Endphalanx des Fingers Ein Streifen der dorsalen Haut des Fingers wird verwendet derartig dass sein distales Ende an

der Endphalanx befestigt bleibt Der Hautstreifen wird mittels Mercelennähten an die proximale Aponeurose genäht Die von ihrer Basis gelöste Haut an den Fingerseiten wird nun über den Streifen genäht Der Finger wird 3–5 Wochen ruhiggestellt Die Nähte verursachten in fast allen Fällen eine oberflächliche Infektion was jedoch das Behandlungsergebnis nicht störte Die Sehne heilte gut in allen Fällen von einfachen subkutanen Rupturen und von Rupturen im Zusammenhang mit einer Wunde obwohl die Mehrzahl erst über drei Wochen nach dem Schaden behandelt wurden In Fällen mit lacerierten Wunden war der Erfolg unsicher

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OSTEOARTHRITIS OF THE HIP TREATED WITH INTERTROCHANTERIC DISPLACEMENT OSTEOTOMY

A Follow-up Study

By

ULF LUCHT & MOURITZ TARP

Received 11. IX. 66

In 1919 *Lorenz* described his bifurcation operation. It was primarily used for the treatment of congenital dislocation of the hip, but in a later publication (1925) he mentioned as one of the indications "the most serious cases of painful arthritis deformans". *McMurray* in 1935 described an oblique osteotomy above the level of the lesser trochanter with medial displacement of the femoral shaft for the treatment of unilateral osteoarthritis of the hip. Independently *Malkin* described displacement osteotomy one year later. In 1950 *Pauwels* introduced varus osteotomy without displacement. This method he had used particularly for young adults with painful dysplasia of the hip. Later, this angulation was combined with displacement. During the past 15 years several modifications have been devised.

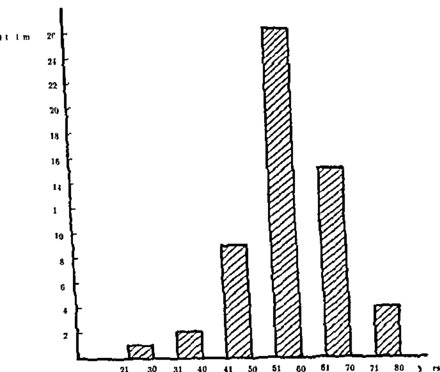
That the relief of pain was of long duration was demonstrated by *Osborne & Fahrni* (1950), *Wardle* (1955), *McFarland* (1957), *Adam & Spence* (1958) and *Ottolenghi & Frigerio* (1962). Improvement of the radiographic appearances following osteotomy has been reported by, int. al., *Osborne & Fahrni* and *Adam & Spence*. The majority of the patients in the above mentioned studies have had the operation at an advanced stage of their disease, and a number of them have been treated postoperatively with prolonged external fixation.

In 1963 *Nissen* and in 1964 *Harris & Kirwan* published their reports on osteotomy in early cases of primary osteoarthritis of the hip. These authors found better results in respect to pain, mobility and X-ray findings in these patients compared with patients with longer lasting and more severe osteoarthritis.

der Endphalanx befestigt bleibt. Der Hautstreifen wird mittels Mercelennähten an die proximale Aponeurose genäht. Die von ihrer Basis gelöste Haut an den Fingerseiten wird nun über den Streifen genäht. Der Finger wird 3–5 Wochen ruhiggestellt. Die Nähte verursachten in fast allen Fällen eine oberflächliche Infektion, was jedoch das Behandlungsergebnis nicht störte. Die Sehne heilte gut in allen Fällen von einfachen subkutanen Rupturen und von Rupturen im Zusammenhang mit einer Wunde, obwohl die Mehrzahl erst über drei Wochen nach dem Schaden behandelt wurden. In Fällen mit lacerierten Wunden war der Erfolg unsicher.

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F gure 1 Distributi n f osteotomies on the Je 0 ups

3 f nee operati n 2 Voss perati n 1 an l ost (tomy 1) All had obtained some relief of pain by these peratio ns but the ymptoms had recurred

F ll u up Peri l

The f llow up as l ne at least year after the operati n In 34 steotomies the f ll w up per d nge l fr m 2 t 5 years and in 23 tetomies fr m 5–8 ears

Op r t e T chnique

All the o teot mi we e car ied o it by the s me technique O ily inte nal fixati n w u ed with B sw th pline (Fig ire 2)

Th method i f ll ws The patient i pla ed on a tractio i table and an in ci ion is m de f m the tip f the greater trochanter and carried to bout 15 cm di tally The il tib al tract is di ided the va tus lateralis is incise l and divided by llint li ecl n f r length of 6 8 cm The femur is tripped on the lateral a pe t an l th intert ch nt ic egi n exposed Thereafter the l ne is enci cled by a Gigl w an l after t h s l een en ured that the aw i p oxim l t the lesser trochante the l n i awn ol l quely—fr m the me lial pr ximal aspect to the l t al di tal li ecti n If a algus or varu positi n is to be c rrected 2 Gigli saws re appl l and a we lge i rem e l Thereafter the distal fr gment of the femur is

What the operation aims at according to *Duthie* (1964) is (1) to relieve pain (2) to correct deformities (3) to retain or improve stability (4) to retain or improve mobility.

PRESENT MATERIAL

The present material comprises the patients treated during the period 1957–1964 in the Orthopaedic Department of the Odense County and City Hospital for osteoarthritis of the hip by intertrochanteric displacement osteotomy.

The main indication for the operation was pain. No regard was paid to the severity of the osteoarthritis in deciding upon the operation.

A total of 61 patients had the operation. Six died more than 3 months after the operation. Among the remaining 55 two were operated on bilaterally, so that the series represents 57 operations. All 55 patients were examined postoperatively. 35 operations were performed on the right and 22 on the left hip.

Sex Ratio

34 operations were performed on women and 23 on men. This female preponderance is apparent also from most other publications on the surgical treatment of osteoarthritis of the hip (*Cade* 1947, *Nicoll & Holden* 1961, *Ottolenghi & Frigerio* 1962, and *Ferguson* 1964).

Age Distribution

The average age at operation for the entire series was 57 years (26–76 years). 88 per cent were in the range 41–70 years (Figure 1). The age distribution corresponds to that reported by others.

Primary and Secondary Osteoarthritis

The cause of primary osteoarthritis is unknown, while secondary osteoarthritis develops as a consequence of abnormality in the joint. Our series includes 5 cases of secondary osteoarthritis, i.e. 1 old epiphysiolysis, 1 old fracture of the femoral neck, 1 case with a history of operation for congenital dislocation of the hip, and 2 cases of acetabular dysplasia. The others must be considered primary.

Bilateral Osteoarthritis of the Hip

In 29 cases (51 per cent) there was radiographic evidence of bilateral osteoarthritis, while in the remaining 28 cases the other hip was normal. *Shepherd* (1960) found 43 per cent bilateral cases among patients treated with osteotomy, *Nicoll & Holden* (1961) 46 and 18 per cent and *King & Dewey* (1965) 51 per cent bilateral.

Previous Treatment

48 patients (84 %) previously had conservative treatment (short wave therapy, massage, X-radiation and injections) with no effect or an effect of only brief duration. Conservative treatment is stated to be of very doubtful value in osteoarthritis of the hip (*De Marneffe et al.* 1965).

Seven patients had previously been treated surgically by operation (fenestration

Table 1 Preoperative duration of pain

	Pain on weight bearing	Pain at rest
None	0	12
<1 year	5	13
1 5 years	20	24
>5 years	32	8
	57	57

In analysing the postoperative results 2 osteotomies have to be excluded as these patients were later subjected to Girdlestone s operation

At follow up it was found that 34 osteotomies had resulted in the complete relief of pain while 18 had reduced the pain and 3 had had no effect on the pain No patient had increased pain In other words the pain had disappeared or been reduced after a total of 52 osteotomies or in 95 per cent (Table 2)

Table 2 Pain at follow up in relation to preoperative duration of pain

Pain on weightbearing	None No	%	Decreased No	%	Unchanged No	%
<1 year	4	80	1	20	0	0
1 5 years	12	63	4	21	3	16
>5 year	18	58	13	42	0	0
	34	62	18	33	3	5
Pain at rest	46	84	8	14	1	2

These figures correspond to the findings of others *Adam & Spence* (1958) 57 osteotomies with improvement of pain in 81 per cent *Robins & Piggot* (1960) 64 osteotomies with improvement of pain in 92 per cent *Nicoll & Holden* (1961) 195 osteotomies with improvement of pain in 88 per cent *Ottolenghi & Frigerio* (1962) 103 osteotomies with improvement of pain in 94 per cent and *Howe et al* (1963) 76 osteotomies with improvement of pain in 97 per cent

The relief of pain is largely independent of the duration of the disease before the operation as only a very few patients had had pain for less than 1 year (Table 2)



Figure 2 Bosworth's spline

displaced medially the aim being a displacement of about half the width of the bone and the tip of a Bosworth spline is knocked up through the osteotomy surface and the trochanter After correction of a rotation contracture if any the spline is fixed to the femur with 3–5 screws Prior to the fixation a good contact between the osteotomy surfaces must be secured The vastus lateralis and the iliotibial tract are sutured with catgut and the skin with nylon or steel wire

The Bosworth spline is easy to apply It fixes rotation flexion and abduction

X ray exposures were not made during the operation The first check up film was taken 7–14 days after the operation and then usually again 3 months after the operation

Postoperative Regimen

A few days after the operation the patients were allowed to sit At the end of 1 2 weeks they were started on walking exercises and they were permitted to put the operated leg to the floor but not to subject it to weight bearing When the patient could manage confidently with 2 English canes they were discharged If X ray films 3 months after the operation showed union they were given permission for full weight bearing Anticoagulant medication was not used in any instance in connection with the operation

RESULTS

Pain

All the patients had pain on weight bearing prior to the operation and in 32 this pain had lasted for more than 5 years Before the operation 15 had pain at rest (Table 1)

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The relief of pain is largely independent of the duration of the disease before the operation as only a very few patients had had pain for less than 1 year (Table 2)

At follow up the pain at rest had disappeared or decreased in 54 patients and was unchanged in 1 (Table 2)

If the pain is regarded in relation to the length of the follow up period the best results are apparently found in the group with the shorter follow up period but there is not a significant difference between the 2 groups (Table 3)

Table 3 Pain at follow up in relation to follow up period (I) number of diseased hips (II) and degree of osteoarthritis (III)

	Pain					
	None		Decreased		Unchanged	
	No	%	No	%	No	%
I						
Follow up period 2–5 years	24	73	9	27	0	0
Follow up period 5–8 years	10	45	9	41	3	14
II						
Unilateral osteoarthritis	22	79	6	21	0	0
Bilateral osteoarthritis	12	44 5	12	44 5	3	11
III						
Mild osteoarthritis	6	46	6	46	1	8
Severe osteoarthritis	28	67	12	28	2	5

Shepherd (1960) found practically no difference between a follow up period of 5–7 years and 7–10 years *Ottolenghi & Frigerio* (1962) found that in 60 cases followed for 1–3 years 85 per cent were relieved of pain and among 43 cases followed for 3–17 years 86 per cent were free of pain

The results as far as the relief from pain is concerned is better in unilateral cases (79 per cent relieved of pain against 44 5 per cent in bilateral osteoarthritis) This difference is significant ($p<0.01$) (Table 3) *Shepherd* (1960) reported that the relief from pain was greater in unilateral cases *Muller* (1957) as well as *Nicoll & Holden* have stated moreover that in bilateral osteoarthritis the complaints about the un operated hip often increase when the pain from the osteotomized side has been reduced We have also observed this phenomenon but not constantly

There is no relationship between age at the time of operation and the result at follow up in respect to pain The same has been demonstrated by *Adam & Spence* (1958)

Harris & Kirwan (1964) reported a greater relief from pain after osteotomy *in patients with early cases of primary osteoarthritis.* When considering 13 of our mildest cases (with no radiographic deformity of the head before the operation and a preoperative flexion of at least 30°) we did not find better results than in the remainder of the series (Table 3).

Consumption of Analgesics

At follow up 43 patients were not using any analgesics and 10 were using *less than before the operation. In 2 the analgesic intake was un*changed. No patient had an increased analgesic intake, and no patient had any major consumption of these drugs.

Walking Distance

28 patients could walk farther than before the operation, while in 16 *the walking distance was unchanged and in 11 reduced.* Thus in a total of 80 per cent the walking distance was unchanged or improved. In *Harris & Kirwan's material of mild cases 65 patients out of 71, or* 92 per cent, had the same or a better walking distance.

Use of Stick

Twenty patients were not using a stick at follow up. The remaining 35 were using one or two sticks, several only 1 stick occasionally. One patient was *using 2 crutches* and 6 patients 2 English canes (*Table 4*). In all 7 the walking distance had been reduced.

A high percentage of *Hirsch's* (1961) patients were using a stick but only a very few of *Ferguson's* (1964).

Table 4. Use of a stick

	Preoperatively	1 year after op	2 years after op	At follow up
1 ordinary stick	18	30	24	21
1 English cane	0	6	6	5
2 ordinary sticks	6	2	2	2
2 English canes	0	7	6	6
2 crutches	0	1	1	1
	24	46	39	35

Occupation

Before the operation 49 patients had had predominantly walking, one predominantly standing and 5 predominantly sedentary jobs.

Fifteen patients had given up their jobs before the operation, 3 changed their occupation after the operation and 2 gave up their jobs after the operation. One of the latter patients was relieved of pain after the operation and in the other one the pain was reduced. It cannot be ruled out that their retirement from work was contributory.

A total of 8 patients had reached the age of 67, i.e. the pension age during the follow-up period.

The working ability was practically unchanged from prior to the operation until the follow up at which only 9 patients were incapacitated, 28 are partially and 18 fully capable of working (Table 5). Partially capable means that the patients can manage light work, e.g. the women can do domestic work except for the heaviest part of it.

25 patients obtained disablement pension including 12 who has this pension before the operation.

Table 5. Working ability

	Preoperatively	At follow up
Full working ability	18	18
Partial working ability	26	28
Incapacitated	11	9
	5	5[illegible]

Mobility

A collected assessment of the mobility in each hip on the basis of the 6 differing movements showed that in 16 cases (29 per cent) the mobility was improved, in 18 cases (33 per cent) unchanged and in 21 cases (38 per cent) worse. The individual movements are shown in Table 6. It is apparent, as is also generally accepted, that the greatest loss of mobility concerns the external-internal rotation and that flexion is best preserved.

By way of comparison the following previous findings may be mentioned. Nicoll & Holden (1961) found that among 28 patients with internal fixation 36 per cent had increased mobility, 39 per cent unchanged mobility and 25 per cent decreased mobility, while the cor

Table 6 Mobility

	Flex–Ext		Abd–Add		Ext rot–Int rot	
	Preop	At follow up	Preop	At follow up	Preop	At follow up
0	1	3	20	15	38	39
1–30	13	15	20	19	13	14
31–60	16	12	11	20	3	2
61–90	18	15	4	1	1	0
>90	7	10	0	0	0	0

responding values for 119 patients with external fixation were 21 per cent, 29 per cent and 50 per cent. *Shepherd* (1960) also found better mobility after internal fixation. *King & Dooley* (1962) found the mobility to be essentially the same as prior to the operation, tending to decrease as the years went by. Among 75 intertrochanteric osteotomies *Ottolenghi & Frigerio* (1962) has 37 per cent with improved mobility, 39 per cent with unchanged and 24 per cent with decreased mobility. *Cauchoix* (1965) reported that nearly all patients treated by McMurray osteotomy lost some mobility. According to *Ottolenghi & Frigerio* the highest degree of mobility was found in patients with 60° flexion or more preoperatively, while a great limitation of motion was often found if the preoperative mobility had been less than 60°. This we cannot confirm, but when comparing preoperative flexion with the flexion at follow up in patients with mild osteoarthritis (as already mentioned no preoperative deformity of the femoral head and at least 30° flexion) and in patients with more severe osteoarthritis (the remainder of the series) we found a better but not significantly better mobility in patients with mild osteoarthritis (Table 7). This is in keeping with the observations of *Harris & Kirwan*.

Table 7 Flexion at follow up in relation to degree of osteoarthritis

	Mild osteoarthritis		Severe osteoarthritis	
	No	%	No	%
Flexion unchanged or better	9	69	23	55
Flexion poorer	4	31	19	45

It is difficult to explain the improvement in mobility but part of the explanation is that mobility inhibited by pain before the operation

will be released. This is apparent from the often perceptibly increased mobility in an anaesthetized patient. Another factor may be the establishment of better mechanical conditions.

In respect to deformities it may be seen that the number of flexion and adduction contractures was almost unchanged from before the operation. On the other hand the number of external rotation contractures had increased by about 3 times (Table 8). This must be because it has not been possible to adjust the distal fragment to a sufficient extent into the correct position before fixing the spline.

Adam & Spence (1958) found little difference between the deformity before and after the operation.

Table 8. Contractures

		Preoperatively	At follow up
Ext. rotation contracture	>10	5	14
Flexion contracture	>20	3	2
Adduction contracture	>10	6	6

There is no relationship between the freedom from pain and the degree of preoperative flexion. A comparison of the mobility at follow up with the attainment of total relief of pain reveals that of those who had reduced mobility 48 per cent were totally free of pain, of those with unchanged mobility 56 per cent, and of those with improved mobility 86 per cent were totally free of pain. It is remarkable that half the patients in the group with reduced mobility were completely relieved of pain. However, this has also been demonstrated by others (e.g. *Ottolenghi & Frigerio* 1962). The explanation is not ankylosis, as in this material there were only 3 ankyloses at follow up, 1 fibrous and 2 bony. *Shepherd* (1960) had 12 per cent ankyloses and *Nicoll & Holden* (1961) 34 per cent at follow up. The last mentioned authors found the incidence of ankylosis to be twice as high when the osteotomy had been followed by fixation in plaster cast as when internal fixation without plaster had been employed. Furthermore, the incidence was related to the movement of flexion prior to the operation: 74 per cent of the hips that ankylosed had had less than 45° flexion before the operation.

In our series we have one hip with pseudarthrosis between the femoral shaft and the pelvis. *Shepherd* had 12 out of 218.

Shortening

41 patients showed shortening of the leg on the operated side. This shortening was from ½–2 cm in 24 patients, from 2 to 4 cm in 15 patients and more than 4 cm in 2 patients. It is due partially to the medial superior displacement of the distal fragment.

Overweight

At follow up 17 patients were overweight. Overweight is defined as 10 per cent in excess of the ideal weight, i.e. the average for the age group 25–30 years in relation to height (values derived from the tables of the insurance company Hafnia). We found no relation between overweight and pain at follow up.

X-ray Findings

On the preoperative X-ray films 41 patients were found to have severe osteoarthritis, 12 moderately severe and 2 mild. In 39 there was incongruence between the femoral head and the acetabulum. 51 patients had sclerosis of the head and acetabulum. 49 had cysts in the head and 44 in the acetabulum. 16 had exostoses on the head and 44 on the acetabulum and in 37 the head was flattened.

At follow up the X-ray appearances had improved in 26, while they were unchanged in 21 and aggravated in 8. The joint space was wider in 29, unchanged in 21 and narrower in 5. Out of the 39 patients with preoperative incongruence 8 showed improvement, while in 28 it was unchanged and in 3 accentuated. Among the 51 patients with preoperative sclerosis the sclerosis was less marked in 27, unchanged in 22 and aggravated in 2 (Figure 3). *Adam & Spence* (1958) found improved X-ray appearances in 38 out of 55, unchanged in 16 and aggravated in 1 case. *Howe et al.* (1963) demonstrated an increased joint space in 47, unchanged in 23 and narrower in 9 cases. *Robbins & Piggot* (1959) felt that the increase of the joint space was due to the altered position of the femoral head and that it was due only occasionally to regeneration of the articular cartilage. It is obvious that in a number of cases the increase of the joint space is due to an altered position of the femoral head, as this is often apparent on films taken a short time after the operation.

A comparison of the degree of the osteoarthritis (the mild cases defined as before) and the X-ray findings at follow up shows better (but

will be released. This is apparent from the often perceptibly increased mobility in an anaesthetized patient. Another factor may be the establishment of better mechanical conditions.

In respect to deformities it may be seen that the number of flexion and adduction contractures was almost unchanged from before the operation. On the other hand the number of external rotation contractures had increased by about 3 times (Table 8). This must be because it has not been possible to adjust the distal fragment to a sufficient extent into the correct position before fixing the spline.

Adam & Spence (1958) found little difference between the deformity before and after the operation.

Table 8. Contractures

		Preoperatively	At follow up
Ext. rotation contracture	>10°	5	14
Flexion contracture	>20°	3	2
Adduction contracture	>10°	6	5

There is no relationship between the freedom from pain and the degree of preoperative flexion. A comparison of the mobility at follow up with the attainment of total relief of pain reveals that of those who had reduced mobility 48 per cent were totally free of pain, of those with unchanged mobility 56 per cent, and of those with improved mobility 86 per cent were totally free of pain. It is remarkable that half the patients in the group with reduced mobility were completely relieved of pain. However, this has also been demonstrated by others (e.g. *Ottolenghi & Frigerio* 1962). The explanation is not ankylosis, as in this material there were only 3 ankyloses at follow up, 1 fibrous and 2 bony. *Shepherd* (1960) had 12 per cent ankyloses and *Nicoll & Holden* (1961) 34 per cent at follow up. The last mentioned authors found the incidence of ankylosis to be twice as high when the osteotomy had been followed by fixation in plaster cast as when internal fixation without plaster had been employed. Furthermore, the incidence was related to the movement of flexion prior to the operation: 74 per cent of the hips that ankylosed had had less than 45° flexion before the operation.

In our series we have one hip with pseudarthrosis between the femoral shaft and the pelvis. *Shepherd* had 12 out of 218.

Table 10 Alteration of the head neck angle as a consequence of the operation

	Varus	Valgus	Unchanged
$\leqq 15$	26	3	13
>15	11	2	
	37	5	13

The displacement at the site of osteotomy was in 23 cases less than half the width of the diaphysis and in 32 more than half the diaphyseal width There is no relationship between the degree of medial displacement and the relief of pain

The metal projects up through the trochanter in 30 patients As already mentioned the spline is intended to penetrate the cortex In 7 the spline projects more than 2 cm In 9 patients there was tenderness at the tip of the spline 17 had pain on maximum passive movement in certain directions but only 2 on abduction alone In 3 cases the spline had been removed because of complications

Complications

The operative mortality was 0 There were no infections and no cases showing any reaction around the spline One patient had severe phlebitis but without emboli No patient developed limitation of movement in the knee

Table 11 Healing time

	Number of osteotomies
≤ 3 months	41
3 6 months	9
6–12 month	2
Pseudarthroses	5

50 osteotomies had united within 6 months including 41 within 3 months In 2 union was delayed taking up to 1 year There were 5 pseudarthroses (Table 11) The cause of the delayed union in the 2 cases was poor contact at the osteotomy site while the causes of the pseudarthroses were as follows In 2 patients marked displacement and poor contact at the osteotomy site in 1 patient the osteotomy line was



Figure 3. (A) Preoperative film showing severe right sided osteoarthritis of the hip in a 43 year old man. (B) The same hip two weeks after osteotomy. (C) The same hip 3 years after the operation. Regression of the osteoarthritic changes.

not significantly better) results in mild cases (Table 9). This is in accordance with the findings of *Harris & Kirwan*.

On comparison between absolute relief from pain and post operative X-ray appearances we found that of the patients with aggravated X-ray appearances 62 per cent were totally relieved of pain, while among those with improved appearances 73 per cent were totally free of pain. In other words there is no relationship and we found strangely enough that 62 per cent were rendered free of pain in spite of poorer X-ray appearances (Table 9).

Table 9. Postoperative X ray findings in relation to pain at follow up and degree of osteoarthritis

	X ray findings		
	Improved	Unchanged	Worse
No pain	19	10	5
Pain decreased	7	9	2
Pain unchanged	0	[illegible]	1
Mild osteoarthritis	1[illegible] (92 %)		1 (8 %)
Severe osteoarthritis	35 (83 %)		7 (17 %)

In two thirds of the patients the head neck angle had altered into varus as a consequence of the operation (Table 10). *Harris & Kirwan* (1964) reported an alteration of this angle into varus in 21 cases, while in 42 cases it was unchanged and in 9 it had altered into valgus. The varus position was not intended but was found to occur more often when a straight V spline was used.

According to *Nissen* (1963) the effect of osteotomy is due to interruption of the active hyperaemia On the other hand *Ottolenghi* (1965) believes that in osteoarthritis there is a question of passive hyperaemia and that osteotomy stimulates the production of an active revascularization and repair of the lesions

A common result of all osteotomies is major or minor reduction of pain major or minor correction of deformities major or minor regression of the degenerative process Simple transverse osteotomy in the trochanteric region without displacement or angulation will alleviate the pain like medullostomy (*McKenzie* 1936) but it will not make the degenerative process regress (*Blount* 1964) Unless the deformity is corrected the pain will return when activity is resumed (*Ferguson* 1964) Several authors find that medial displacement is not of decisive importance (*Malkin* 1936 *McFarland* 1954 *Campbel & Jackson* 1955 *Ferguson* 1964)

In performing the osteotomies we have considered medial displacement to be an important part of the operation which has been carried out in all cases However we did not find any relation between pain and degree of displacement The head neck angle had altered into varus in two-thirds of the cases but this was not intended except in a few In 39 patients with incongruence between the femoral head and the acetabulum the congruence had improved in 8 was unchanged in 28 and worse in 3 There were relatively few contractures but we did not succeed in correcting them On the contrary the number of external rotation contractures increased The explanation of the less marked (but not significantly less marked) relief of pain in the group with a long follow up period than in the group with a short follow up period is possibly that the mechanical problems have not been satisfactorily solved

CONCLUSION

Out of 55 patients 34 (62 per cent) were totally relieved of pain by intertrochanteric displacement osteotomy In 52 patients (95 per cent) the pain disappeared or decreased The total relief of pain is significant ly higher in patients with unilateral osteoarthritis of the hip There is no relationship between age and freedom from pain between the degree of preoperative flexion and pain or between the X ray findings and relief of pain

In respect to the correction of deformities the number of flexion and

below the level of the lesser trochanter; in 1 patient the spline was in an incorrect position, as it projected into the head and possibly into the joint. In the fifth case there had been primary union, but one year after the operation the patient sustained a fracture of the femoral neck which involved the osteotomy line and resulted in pseudarthrosis at the osteotomy site. Two of these 5 patients have later had Girdlestone's operation, 1 united after re-osteotomy, and the last 2 have not had further treatment as they are free of pain. In the literature the incidence of pseudarthrosis ranges from 0 (*Harris & Kirwan* 1964) to 18 per cent (*Crellin & Simurda* 1965). The causes stated are mainly lack of contact at the site of osteotomy and technical errors.

DISCUSSION

In the surgical treatment of osteoarthritis of the hip there is a choice of 3 main types of operation, each having its indication, viz. arthrodesis, arthroplasty and osteotomy. Other operations for this disease should be considered merely palliative. Osteotomy is the simplest to perform but the least understood (*Blount* 1964).

It is evident, however, that the X-ray changes are reversible and may regress following osteotomy. In respect to the way in which the osteotomy works most authors agree that a biochemical problem is involved. The mechanical factors comprise better centering of the femoral head in the acetabulum with increased contact area, better congruence of the joint surfaces, a more even distribution of pressure upon the joint surfaces, better distribution of weight bearing upon the femoral head and neck, correction of deformities, and decreased muscular and capsular tension. *McMurray* (1939) and *Pauwels* (1951) assumed that these factors were primarily responsible and based their operations on them. *Pauwels* has later (1961) established that osteoarthritis is a biomechanical problem consisting of 2 factors, viz. the mechanical stress exerted upon the joint and the biological state of the articular cartilage.

The biological process has not yet been elucidated, but vascularization factors appear to play an important role. *Harrison, Schajowicz & Trueta* (1953) and *Rutishauser & Grasset* (1955) have demonstrated the presence of a hyperaemic process in osteoarthritis of the hip (the former active and the latter passive hyperaemia). It has been demonstrated also that the hyperaemia is localized in the marginal region of the osteoarthritic lesions. The collapsed articular cartilage, the sclerosed areas and the subchondral lesions are ischaemic injuries.

RESUME

Pendant la periode entre 1957 et 1964 57 osteotomies de deplacement intertrochanterien ont éte pratiquees chez 55 malades souffrant d osteo arthrite de la hanche Tous ces malades ont ete suivis La fixation a ete exclusivement externe par tige Bosworth La technique est de crite

Dans 52 des 55 cas (95 pour cent) il y a eu soulagement ou reduction des douleurs tandis que l etat est reste inchange chez 3 La mobilite s est ameliorée ou est restee inchangee dans 62 pour cent des cas et elle est moins bonne dans 38 pour cent des cas Les trouvailles radio logiques sont meilleures ou einchangees dans 85 pour cent des cas et moins bonnes dans 15 pour cent des cas Il s est produit cinq pseud arthroses Les resultats les plus favorables ont ete observes dans les cas precoces et unilateraux mais l application de la methode est ce pendant aussi justifiée dans les cas plus graves d osteoarthrite

ZUSAMMENFASSUNG

Während der Zeitspanne 1957 1964 wurden 57 intertrochanterische Verschiebungsosteotomien an 55 Patienten mit Osteoarthritis der Hufte vorgenommen Alle Patienten wurden nachuntersucht Die Hauptan zeige fur den Eingriff war Schmerzen Die Fixierung geschah aus schliesslich intern mittels der Bosworth Schiene In 52 von 55 Fällen (95 Prozent) waren die Schmerzen verschwunden oder erleichtert während sie in 3 Fallen unverandert waren Die Beweglichkeit war in 62 Prozent gebessert oder unverandert und herabgesetzt in 38 Prozent Die Rontgenbefunde waren in 85 Prozent gebessert oder unverändert und in 15 Prozent verschlechtert Pseudarthrosen entstanden in 5 Fal len Die besten Ergebnisse wurden bei fruhzeitigen und einseitigen Fallen beobachtet aber die Methode ist auch bei schwereren Fallen von Osteoarthritis gerechtfertigt

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adduction contractures was unchanged, while the number of external rotation contractures was three times higher at follow-up than before the operation.

If the stability is expressed in terms of walking distance, this was improved or unchanged in 80 per cent and decreased in 20 per cent.

In a collected assessment of mobility, improved or unchanged mobility was found in 62 per cent and poorer in 38 per cent. Comparison of preoperative flexion and flexion at follow-up in patients with mild osteoarthritis (defined as mild or moderate X-ray signs without deformity of the head and preoperative flexion exceeding 30°) and in patients with severe osteoarthritis showed better (but not significantly better) mobility in the group of mild osteoarthritis.

The total X-ray appearances were better or unchanged in 85 per cent and poorer in 15 per cent. The appearances were better (but not significantly better) in patients with mild cases (defined as above).

There were 5 cases of pseudarthroses—2 due to marked displacement and poor contact, 2 to inadequate technique and 1 due to fracture after primary healing.

Summing up, it may be said that our results correspond largely to those reported by others. The most favourable results are obtained by operations on early unilateral osteoarthritis, and it seems to be important to aim at a result as mechanically satisfactory as possible. But in more long-standing and more severe cases too the results are acceptable, decreasing with increasing limitation of movement and radiological destruction.

SUMMARY

During the period 1957–1964 57 intertrochanteric displacement osteotomies were performed on 55 patients with osteoarthritis of the hip, all of whom have been followed up. The main indication for the procedure was pain. Fixation was exclusively internal by Bosworth's spline. The technique is described. In 52 out of the 55 cases (95 per cent) the pain was relieved or reduced, while in 3 cases it was unchanged. Mobility was improved or unchanged in 62 per cent and poorer in 38 per cent. The X-ray findings were better or unchanged in 85 per cent and poorer in 15 per cent. Five pseudarthroses occurred. The most favourable results were observed in early and unilateral cases, but the method is also justified in the more severe cases of osteoarthritis.

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TRAUMATIC PREMATURE CLOSURE OF THE DISTAL TIBIAL EPIPHYSEAL PLATE

By

A LANGENSKIÖLD

Received 17 1 67

In his book on fractures in children *Blount* wrote (p 181) The *distal tibial epiphysis is the most prone of any in the body to the type of injury that causes damage to the epiphyseal plate and subsequent angular deformity and/or shortening The same opinion was expressed* by *Salter & Harris* in 1963 *Bergenfeldt* (1933) also pointed out the relatively high frequence of epiphyseal injuries in the ankle region In 1957 *Bartl* stated that growth disturbance is seldom seen after adequate treatment of closed epiphyseal injuries in the ankle *Carothers & Crenshaw* found a high incidence of permanent damage to the epiphysis in adduction injuries of the ankle However the number of articles dealing with the treatment of manifest growth disturbance after injury to the distal tibial epiphyseal plate is very small

In an article on traumatic arrest of epiphyseal growth at the lower end of the tibia *MacFarland* (1931) described the type of osteotomy which is indicated by varus deformity of the ankle after skeletal growth is completed About the possibilities of preventing deformity in this type of injury he wrote (p 80) Attempts have been made as one could expect to prevent the recurrence or progression of the deformity These have not been definitely successful *Aitken* in 1936 also expressed a pessimistic view as to the possibilities of preventing deformity after severe injury to the distal tibial epiphyseal plate

McFarland wrote his article two years before *Phemister* published his work on the operative arrest of growth Today epiphyseodesis is a safe method of preventing any angulation deformity provoked by partial closure of an epiphyseal plate Osteotomy with over correction



Figure 1 Case 1 Age seven years and three months Varus deformity of the ankle two years and four months after injury

or repeated osteotomies are especially in young children alternatives which might give a possibility of gaining some length of the extremity

In the four cases described below severe traumatic growth disturbance of the lower end of the tibia indicated several operations to correct and prevent varus deformity and discrepancy of leg length





Figure 2 Case 1 The right ankle three months after supramalleolar osteotomy of the tibia and the fibula



Figure 3. Case 1. Age ten years and two months. Progression of deformity had been arrested by epiphyseodesis of the lateral malleolus two years and eight months previously.

Case 1. S. M., a girl, born June 25, 1949. On June 10, 1954 a falling gravestone caused an open fracture of the distal end of the right tibia. The patient was first seen by the present author in October 1956 (Figure 1). There was marked varus deformity of the right ankle, complete growth arrest of the distal tibial epiphyseal plate and suppuration from a fistula above the medial malleolus.

Four months after revision of the fistula, supramalleolar osteotomy of the right tibia and fibula was performed (Figure 2). There was a definite tendency to recurrence of varus deformity by overgrowth of the distal end of the fibula. Three months after the osteotomy a Phemister type of epiphyseodesis of the lateral malleolus was performed (Figure 3). At that time there was a one and a half centimeter shortening of the limb. From the age of eight years to the age of twelve shortening increased to three and a half centimeters. After epiphyseodesis of the upper ends of the left tibia and fibula the shortening diminished and was

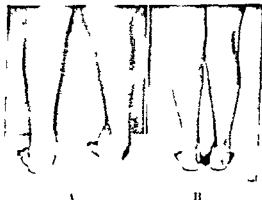


Figure 4. Case 1. A. Age seven and a half years. Varus deformity of right ankle before treatment. B. Age twelve years and nine months. Very slight deformity of the right ankle.

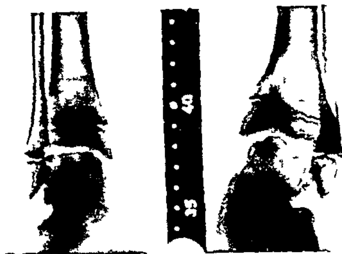


Figure 5 Case 2 Age eleven years Varus deformity of the left ankle four years after fracture

two and a half centimeters when growth was finished A slight varus deformity remained in the right ankle (Figure 4)

Case 2 T U a girl born December 6 1945 At the age of seven years she was treated in a general hospital for a fracture of the left ankle After this a varus deformity of the ankle gradually developed The child was eleven years when she was first seen by the present author There was partial arrest of epiphyseal growth in the medial part of the distal tibial epiphysis (Figure 5) and a one and a half centimeter shortening of the left leg Osteotomy of the distal ends of the left tibia and fibula was performed (Figure 6) and nine months later epiphyseodesis of the upper ends of the right tibia and fibula was carried out The shortening increased to two centimeters and at the age of thirteen epiphyseodesis of the distal end of the right femur was performed

When the patient was fourteen the varus deformity had recurred and the distal epiphyseal plate of the fibula was still open (Figure 7) As the skeletal age of the patient was only thirteen at the chronologic age of fifteen and a half epiphyseodesis of the lateral malleolus was performed to prevent further progression (Figure 8) At the end of the growth period discrepancy of leg length was one centimeter Re t tomy of the tibia and fibula was performed after which a satisfactory result was achieved (Figure 9)

Case 3 J D a boy born November 30 1957 In a motor accident when he was four years old he sustained an open fracture of the distal end of his right tibia and a severe crushing injury of his right foot and ankle After plastic surgery for xt ns se rs it was possible to consider the treatment of a varus deformity of the right ankle (Figure 10) After osteotomy of the distal ends of the right tibia and fibula the foot was in good position (Figure 11) There was complete arrest

Figure 6 Case 2 Radiograph taken two months after correction of varus deformity by osteotomy of the tibia and fibula





Figure 7 Case 2 Age fourteen years Varus deformity of the left ankle progressing three years after osteotomy

of growth of the distal tibial epiphyseal plate and overgrowth of the fibula was threatening the result of treatment (Figure 12) Thirteen months after the osteotomy epiphyseodesis of the lateral malleolus was performed and at the age of eight years a permanent and acceptable position of the ankle seemed to have been achieved (Figures 13 and 14) At the age of nine years there was a two centimeter shortening of the right leg which will require further treatment

Case 4 A boy born July 22 1950 When the boy was five years his left ankle was injured by a tractor and varus deformity of the ankle gradually developed

The boy was first seen by the present author when he was nine There was varus and recurvatum deformity in the left ankle and complete arrest of growth of the distal tibial epiphyseal plate (Figure 15) Osteotomy of the distal ends of the tibia and fibula and epiphyseodesis of the lateral malleolus were carried out (Figure 16) There was a three centimeter shortening of the left leg

Epiphyseodesis of the upper ends of the right tibia and fibula was performed at the age of eleven and of the distal ends of the right tibia and fibula at the age of



Figure 8 Case 2 Age sixteen years and eleven months Progression of varus deformity arrested by epiphyseodesis of the lateral malleolus at the age of fifteen and a half years skeletal age being thirteen years



Figure 9 Case 2 Final position of the left ankle after osteotomy

twelve and a half years When growth was finished there was a *one centimeter* shortening of the left leg and the position of the left ankle had remained good (Figures 17 and 18)

DISCUSSION

In case 1 there was complete arrest of growth in the distal end of the tibia when correction by osteotomy was performed (Figures 2 and 3) The ankle would have remained in a better position if epiphyseodesis of the lateral malleolus had not been delayed but carried out in connection with the osteotomy

In case 2 varus deformity recurred from continued growth of the distal end of the fibula and the lateral part of the distal tibial epiphysis Very little leg length was gained from repeated osteotomy When a

Figure 10 Case 3 Age five years and ten months Varus deformity of the right ankle one year after injury





Figure 11 Case 3 Age six years and six months Radiograph taken two months after correction of varus deformity by osteotomy of the right tibia and fibula

large bony bridge connects the medial part of the distal tibial epiphysis to the metaphysis epiphyseodesis of the distal ends of both bones should be considered as an alternative to the acceptance of recurrence of deformity and subsequent repeated osteotomy In this case the recurrence unnecessarily caused added irregularity of the ankle joint

In case 3 the degree of growth disturbance in the distal end of the tibia could not be judged with certainty at the time of correction by osteotomy (Figure 11) Follow up examination disclosed the risk of recurrence of deformity from overgrowth of the lower end of the fibula and epiphyseodesis of the lateral malleolus could be carried out in time to prevent it

In case 4 complete arrest of growth of the distal tibial epiphyseal plate clearly indicated epiphyseodesis of the lateral malleolus at the time of osteotomy This case is also the only one in which the present



Figure 12 Case 3 Age seven years and five months Recurrence of varus deformity by overgrowth of the fibula threatening



Figure 13 Case 3 Age eight years and five months Radiograph taken eleven months after epiphyseodesis of the lateral malleolus

author has performed epiphyseodesis of the distal ends of the tibia and the fibula in the sound leg

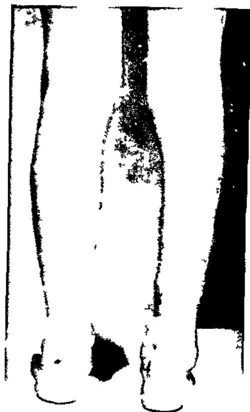
SUMMARY AND CONCLUSIONS

In four cases of traumatic arrest of growth in the distal epiphyseal plate of the tibia epiphyseodesis of the distal end of the fibula was indicated in addition to corrective osteotomy of the tibia and the fibula Epiphyseodesis of the lateral malleolus should always be carried out when complete premature arrest of growth of the distal end of the tibia is diagnosed and the distal end of the fistula is still growing When a large bony bridge connects the medial part of the distal epiphysis of the tibia to the metaphysis epiphyseodesis of the distal ends of both tibia and fibula should be considered as an alternative to the acceptance



A

Figure 14. Case 3. A. Age six years. Varus deformity of the right ankle before treatment. B. Age seven and a half years. The condition after operative treatment of the right ankle.



B

of progression or recurrence of deformity and subsequent correction by osteotomy.

RÉSUMÉ

Dans quatre cas d'arrêt traumatique de la croissance de la plaque épiphysaire distale du tibia, une épiphyséodèse de l'extrémité distale du péroné était indiquée en plus de l'ostéotomie corrective du tibia et du péroné. Il convient aussi de pratiquer l'épiphyséodèse de la malléole externe lorsqu'un arrêt prématuré de la croissance de l'extrémité distale du tibia est diagnostiqué et que la croissance de l'extrémité distale du péroné continue. Lorsqu'un large pont osseux unit la partie médiane de l'épiphyse distale du tibia à la métaphyse, l'épiphyséodèse des extrémités distales du tibia et du péroné peut être considérée comme une alternative à la progression ou à la récidive de la déformité susceptible de nécessiter une correction par ostéotomie.



Figure 15 Case 4 A and B Age nine years Varus deformity of the left ankle developed after [illegible] fracture at the age of [illegible] years

ZUSAMMENFASSUNG

In vier Fällen von traumatischer Schliessung der Epiphysenfuge am distalen Ende der Tibia war eine Epiphyseodese des distalen Endes der Fibula indiziert ausser der Osteotomie der Tibia und der Fibula. Eine Epiphyseodese des lateralen Malleolus sollte immer ausgeführt werden wenn eine vorzeitige Schliessung der distalen Epiphysenfuge der Tibia vorhanden ist und das distale Ende der Fibula noch weiter wächst. Wenn eine grosse knöcherne Brücke den distalen Epiphysenkern und die Metaphyse vereinigt, sollte eine Epiphyseodese des distalen Endes der Tibia und der Fibula in Betracht gezogen werden als Alternative zum Acceptieren einer Progression oder des Rezidivierens der Deformität und einer späteren Korrektion durch Osteotomie.



Figure 16. Case 4. Left ankle seven months after osteotomy of tibia and fibula and epiphysiodesis of the lateral malleolus.



Figure 17. Case 4. The left ankle at the age of fifteen and a half years.

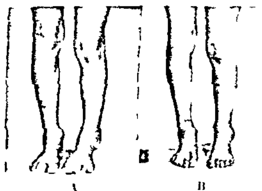


Figure 18. Case 4. A. Age nine years. Varus deformity of the left ankle before treatment. B. Age ten years and eight months. Improved appearance of the left ankle after operation.

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SURGICAL TREATMENT OF PRESSURE ULCERS IN PARAPLEGICS

By

BÖRJE SUNDELL, AURA PENTTI & ANDERS LANGENSKIÖLD

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Paraplegia may be caused by trauma or disease. The growing problem of people with spinal cord injury caused by motor accidents is very important and more attention should be paid to it. It is always necessary to pay attention to the rehabilitation of the paralyzed patient which *can be delayed by serious complications such as pressure ulcers* in different regions of the body. Pressure sores can be avoided only by meticulous care, careful attention to simple bladder drainage and proper rehabilitation measures (*Gelb* 1952).

A pressure ulcer is usually the result of an excessively long compression of the skin and subcutaneous tissues between an underlying bony prominence and the bed or the chair upon which the patient is resting. Continued pressure interferes with the circulation of blood in the tissues and the resulting anoxia leads to necrosis. In deep ulcers the underlying bone becomes exposed and infected (*Groth* 1942, *Blocksma, Kostrubala & Greeley* 1949, *Gelb* 1952).

The results of surgical closure of pressure ulcers has been reported by numerous authors. The main principles of surgery were already outlined 10–20 years ago (*Kostrubala & Greeley* 1947, *Conway & Griffith* 1956).

It is our intention to report on the management of pressure ulcers in paraplegics treated in the Orthopaedic Hospital of the Invalid Foundation.

MATERIAL

There is no special spinal cord injury centre for paraplegics in Finland. Patients with paraplegia are therefore taken care of in all hospitals. A selected group of patients admitted mainly for orthopaedic treatment and rehabilitation to the

Orthopaedic Hospital of the Invalid Foundation were also operated upon for pressure ulcers. During a 10 year period 1956–1966 75 patients were operated upon for pressure ulcers in the sacral area, the greater trochanter area and the area of the ischial tuberosities. Altogether 127 ulcers were treated surgically.

Until 1961 there was no surgeon specialized in plastic surgery working at the hospital but since then a consultant plastic surgeon has taken care of the most difficult pressure ulcer cases. Before 1961 all the operations were performed by the surgeon in charge of each department.

Table 1 shows the distribution of the patients with pressure ulcers. The material consists of 63 paraplegics and 12 quadriplegics.

Table 1. Distribution of patients with pressure ulcers treated at the Orthopaedic Hospital of the Invalid Foundation during the years 1956–1966

Number of patients	75
with paraplegia	63
with quadriplegia	12
Age	
0–19 years	15
20–59 years	60
Sex	
Males	68
Females	7

Table 2. Etiology of the spinal cord injury

Motor accidents	25 patients
Falls	24
Myelitis	8 "
Military service	4 "
Gunshot	3
Diving	1
Miscellaneous	10
Total	75 patients

ETIOLOGY

Only 4 patients sustained their spinal cord injuries during military service but civilian motor accidents and falls together accounted for the largest number (49 patients or 65 per cent). Eight patients had a paraplegia caused by myelitis (Table 2).

According to clinical tests and X-ray examinations the level of the spinal cord damage in 20 cases was found to be in the cervical part, in

18 cases in the upper thoracic part, in 33 cases in the lower thoracic part and in 13 cases in the lumbar part. No accurate correlation could be found between the level of the damage and the site or the frequency of the pressure ulcers.

Site of occurrence. Knowledge of the sites of predilection is useful from the standpoint of prophylaxis. Numerous studies have been reasonably well documented (*Gelb* 1952, *Yeoman & Hardy* 1954 and *Guttman* 1955).

In this material only sacral ulcers, greater trochanteric ulcers and ischial ulcers were taken into consideration. These ulcers give the patient most trouble and interfere with his rehabilitation program (*Griffith & Schultz* 1961 and *Harding* 1961).

Table 3 shows that among a total of 127 pressure ulcers 46 were located in the sacral area, 48 in the area of the greater trochanter and 33 in the area of the ischial tuberosity.

We are usually inclined to think of these lesions in terms of their chronicity but it should be realized that there is often an acute phase in many of them. An incipient pressure ulcer may be mistaken for an abscess and may be incised for drainage of pus that is not present. In ulcers of the chronic form the tissue destruction often extends through fascia, muscle, synovial membrane and even into joints. In this material there was suppurating arthritis in the joint in 2 cases caused by extension of the pressure ulcer through the tissues.

SURGICAL TREATMENT

The patient should be prepared for surgery with a high protein diet. The surgical closure of the pressure ulcer should be performed as soon as the patient's hemoglobin has reached the level of 12 grams and the level of the plasma protein has been brought above 6 mg per 100 ml.

The elimination of muscle spasm is important because spasm may contraindicate operative repair. The spasm should be controlled by neurosurgical procedures but some patients are very reluctant and do not want to accept flaccid paralysis. In this material there were only a few patients in whom the muscle spasm was relieved by alcoholic injection.

Urinary infection should be controlled before the patient is subjected to operation. Urological procedures to relieve urinary retention are performed before surgical repair.

Local preoperative preparations. Local treatment of the pressure



Figure 1. A. *A very large sacral pressure ulcer with considerable surrounding scar tissue. The ulcer had previously been covered with split thickness skin grafts without success.* B. *Closure accomplished with two large rotation flaps after excision of the ulcer and the scar tissue. Thick split thickness skin grafts were used to cover one of the flap donor sites. There was no recurrence after two years.*

ulcer aims at securing a surgically clean wound. Most pressure ulcers require surgical debridement of the necrotic material. Enzyme preparations should not be relied on because they do not clean the ulcer effectively. Moist dressings of 0.5 per cent of Dakin's solution are applied to the ulcer and changed every 4 to 6 hours. The surrounding skin is protected from irritation by a thick film of some protective ointment. The dressings are changed for moist saline dressings applied for 24 to 48 hours before the operation.

Choice of procedure. The basic principles of the surgical treatment are excision of the ulcer and the affected tissue surrounding it, including removal of bony protuberances and restoration of an intact skin surface with adequate subcutaneous padding at the site of the former pressure ulcer (*Blocksma, Kostrubala & Greeley* 1949; *Guttman* 1955; *Conway & Griffith* 1956; *Campbell* 1959).

In most patients there was no need for any kind of anesthesia.

Although split thickness skin grafts are not considered sufficient cover for pressure ulcers, they were quite often used as a dressing graft during the period 1956-1960 (Table 3).

Sacral ulcers. Thirty two sacral ulcers and the surrounding scar

tissue were excised. The exposed bony prominence, however, was partly *resected in only 8 cases* and a large rotation flap was used for covering the defect. In 14 ulcers, the defect was directly sutured (Table 3).

It is important to make the flaps large and not place the suture line directly over bone prominences. Very often a split thickness skin graft was used to cover the flap donor area.

Table 3. Analysis of the surgical methods and the complications in 127 operated pressure ulcers

Surgical methods		Number of operated ulcers			
		Operations	*Complete healing*	*Early complications*	*Late complications*
Sacral ulcers	46				
Excision and suture		14			
Excision and local flap repair		10		1	3
Excision with partial resection of the sacral bone and local flap repair		8	25 (54 %)	3	4
Free skin grafting		14		11	
Trochanteric ulcers	48				
Excision and suture		14		2	
Excision with trochanterectomy and local flap repair		18	18 (37 %)	9	
Free skin grafting		16		10	6
Ischial ulcers	34				
Excision and suture		12			5
Excision and local flap repair		7		2	4
Excision with partial ischiectomy and local flap repair		9	23 (67 %)	2	6
Free skin grafting		6		2	3

Trochanteric ulcers. The location of pressure ulcers over the greater trochanter area seems to present a most difficult problem. In this area muscle spasm interferes very much with the wound healing, which complicates the postoperative treatment. Free skin grafting was used in this group in 16 ulcers, but 10 ulcers did not heal primarily. This method was not considered satisfactory in the treatment of pressure ulcers in this area.



Figure 9 A Large recurrent trochanteric pressure ulcer following an inadequate trochanterectomy and direct closure without flaps The flap used at reoperation is outlined B Closure after thorough resection of the greater trochanter Complete healing occurred A very small recurrent ulcer appeared 2 years later but the original flap was rotated again to cover the defect

For the repair of tissue defects over the greater trochanteric area after the excision of 32 pressure ulcers a rotation flap based infero laterally was preferred in 18 occurrences after resection of the greater trochanter The flap donor defect was covered with split thickness skin grafts

In 14 cases the tissue defect was small and the wound was sutured directly (Table 3)

Ischial ulcers It is important to position the patient in a jack knife fashion on the operating table This position will determine the amount of skin and subcutaneous tissue required for closure after excision of the ulcer In 9 occurrences out of 34 a partial ischiectomy in connection with excision of the ulcer was performed whereas in 19 cases direct suture or local flap repair were performed without bony resection (Table 3)

No radical or total ischiectomy was performed at the first operative procedure

Free skin grafting was not so often used as in the other groups It was used in only 6 occurrences

It should be pointed out that a meticulous hemostasis is very im

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A B

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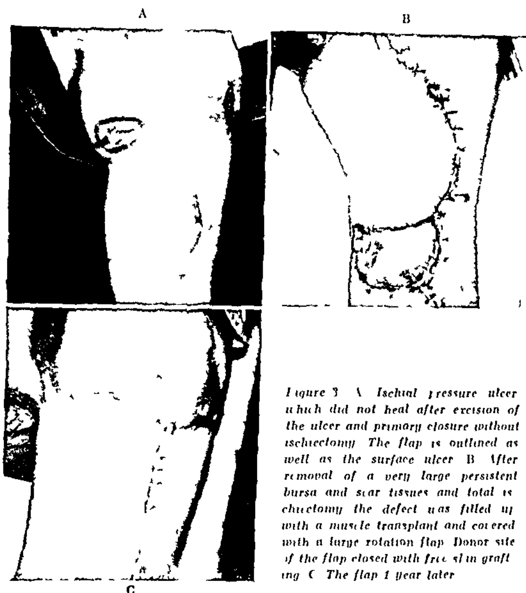


Figure 3. A: Ischial pressure ulcer which did not heal after excision of the ulcer and primary closure without ischiectomy. The flap is outlined as well as the surface ulcer. B: After removal of a very large persistent bursa and scar tissues and total ischiectomy the defect was filled up with a muscle transplant and covered with a large rotation flap. Donor site of the flap closed with free skin grafting. C: The flap 1 year later.

portant. The problem of postoperative hematoma, however, was greatly minimized by continuous postoperative suction drainage left in for at least 4 to 5 days.

Postoperative treatment. All patients with operated pressure ulcers and flap repair were kept prone for 2 to 3 weeks. If the patient could not control his bladder, a urethral catheter was used. A high protein diet and vitamin supplements were given. If healing was uncomplicated the sutures were removed on the tenth to fourteenth postoperative day. By the 3rd week the patient was allowed to start sitting in his wheelchair for 15 to 30 minutes, a period extended gradually up to an hour

RESULTS

A result was considered excellent only if there was primary healing and if sitting was resumed without recurrence

A primary healing was observed in the sacral area in 25 cases (54 per cent) in the greater trochanteric area in 18 occurrences (37 per cent) and in the area of the ischial tuberosities in 23 occurrences (67 per cent) (Table 3)

The complications were mainly due to hematomas infection and to dehiscence of the wound caused by muscular spasm

The use of split thickness skin grafts in the sacral and trochanteric area was not satisfactory In 30 skin grafted ulcers there were early complications in 21 occurrences mainly due to poor take of the skin graft and caused by bad nutrition and infection in the transplantation bed

All the late complications e g recurrent ulcerations in the previously operated area were due to persistent bony prominences

Table 4 Analysis of the surgical methods used in reoperations on 39 recurrent pressure ulcers

Surgical methods		Number of operated ulcers			
		Operations	Complete healing	Early complications	Late complications
Sacral ulcers	8				
Excision with partial resection of the sacral bone and local flap repair		5	7 (88 %)	1	2
Free skin grafting		3			
Trochanteric ulcers	19				
Excision and local flap repair		8	14 (73)		
Excision with trochanterectomy and local flap repair		11		2	
Ischial ulcers	1[illegible]				
Excision with total ischiectomy and local flap repair		12	9 (75 %)		

REOPERATIONS

Thirty nine recurrent pressure ulcers were reoperated. Most of these were operated during the period 1961–1966 (under supervision of a surgeon specialized in plastic surgery).

The surgical procedures were definitely more radical with excision of the recurrent ulcer and surrounding scar tissue and very large flap repair. The application of one of the several methods of closure by flap were determined by the presence of scars adjacent to the pressure ulcer and the regional anatomy.

Table 4 shows the statistics of the reoperations performed.

In the ischial area 12 recurrent ulcers were treated by radical total excision of the ulcer, total ischiectomy and flap repair. Nine ulcers healed completely and 3 ulcers healed after dehiscence of the wound. There were no recurrences of these 12 ulcers in 1–3 years.

The results in the reoperated group show a considerable improvement and an increase in the success of complete primary healing. This certainly demonstrates that the following basic principles must be followed in repair: elimination of the ulcer and adequate replacement of skin and subcutaneous tissue without tension.

FOLLOW UP

The follow up time ranged from a few months to 5 years. There was no recurrence in 21 cases (45 per cent) in the sacral area, in 21 occurrences (43 per cent) in the greater trochanteric area and in 20 occurrences (58 per cent) in the area of the ischial tuberosities (Table 5).

Table 5. Relationship between primary healing, complications, reoperations and non recurrent ulcers in 75 patients operated upon for pressure ulcers

Ulcers		Number of operated ulcers			
		Complete healing	Early complications	Reoperations	No recurrence
Sacral ulcers	46	25 (54 %)	15 (32 %)	8	21 (45 %)
Trochanteric ulcers	48	18 (37 %)	21 (43 %)	19	21 (43 %)
Ischial ulcers	34	23 (67 %)	6 (17 %)	12	20 (58 %)

The operative success in these major sites of pressure ulcers was not satisfactory compared to the percentages reported in other series (*Gelb*

1959 *Griffith & Schull*, 1961) This must be partly due to use of split thickness skin grafts and partly to the unresected underlying bony prominences left behind after the first operation

CONCLUSION

1 The ulcer should be adequately prepared before surgery
2 Free skin grafting is not a method of choice in the surgical treatment of pressure ulcers Routine excision of the ulcer and the underlying bony prominence and flap repair is desirable
3 A meticulous hemostasis is important because postoperative bleeding was the main cause of early complications
4 Plastic surgery for pressure ulcers in paraplegics must be integrated with the entire rehabilitation program the ultimate aim being to get the patient back to essential activities and to walk with braces or ambulate in a wheel chair

SUMMARY

This is a report on 75 paraglegics treated at the Orthopaedic Hospital of the Invalid Foundation for pressure ulcers A total of 127 ulcers in the sacral area in the trochanteric area and in the area of the ischial tuberosities were operated upon by different methods Free skin grafting was used rather often but seemed to be unsatisfactory as a final treatment of the ulcer Excision of the ulcer and the underlying bone prominence and a large flap repair produced the best results

RESUME

Il est rapporte 75 cas de paraplégie traités à l Hopital Orthopedique de a Fondation des Invalides pour ulcères de pression Un total de 127 ulcères dans la région sacrée dans la région trochanterienne et *dans* celle des tuberositées ischiatiques ont été opérés par differentes methodes Des greffes de peau libres ont éte utilisees relativement souvent mais semblent être peu satisfaisantes comme un traitement final de de l ulcère L excision de l ulcère et de la prominence osseuse qui se trouve au dessous avec un large pan de réparation de la peau donne les meilleurs resultats

ZUSAMMENFASSUNG

Dies ist ein Bericht uber 75 Paraplegiker die im Orthopädischen Krankenhaus der Invalidenstiftung wegen Druckgeschwuren behan

delt wurden. Insgesamt wurden 127 Geschwüre der Sacral- und Trochanterregion, sowie im Gebiet der tuberositas ischii operiert mit verschiedenen Methoden. Freie Hautübertragung wurde auch ziemlich häufig angewendet, aber scheint als Schlussbehandlung der Geschwüre nicht zufriedenstellend zu sein. Geschwürexcision und Unterlegung des vorstehenden Knochens mit weiter Lappenbedeckung ergaben die besten Ergebnisse.

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